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RAYMOND C. MOORE
EDITOR

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THE BULLETIN

of the

AMERICAN ASSOCIATION OF PETROLEUM GEOLOGISTS

RAYMOND C. MOORE, *Editor*

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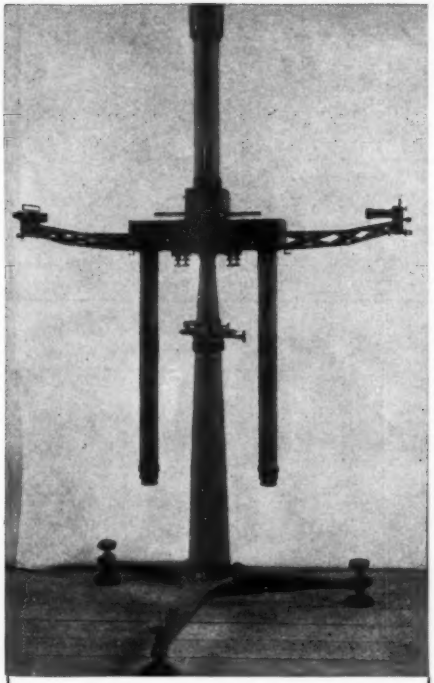

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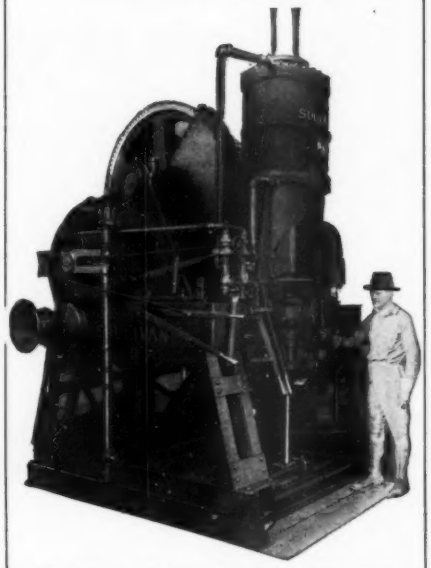

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INTERIOR SALT DOMES OF TEXAS[1]

SIDNEY POWERS

ABSTRACT

This paper describes the geology of the six interior salt domes in eastern Texas and discusses their relationship with the geology of the region and with the interior salt domes of Louisiana.

INTRODUCTION

LOCATION

Salt domes in the United States are confined to the Gulf Coastal Plain of Louisiana and Texas in an area of very thick sediments and gentle folding. One or two domes are reported in the northeastern corner of Mexico near Brownsville and others are suspected under the waters of the Gulf. No salt domes are known east of the western edge of the Mississippi River delta. The salt domes of the Isthmus of Tehuantepec are in a region of similar thick sedimentation and gentle folding, but domes in some other parts of the world are associated with intense mountain building.

Division of the salt domes of the United States into coastal and interior is based on geological and geographical grounds. A broad belt of country coinciding with the outcrop of formations of Oligocene age lies between the groups on the north and those of the coastal belt. Their location is shown in Figure 1.

Interior salt domes are divided into two groups, one on the axis of the geosyncline of eastern Texas, the other near the axis of the

[1] Published by permission of the Amerada Petroleum Corporation.

corresponding geosyncline of northern Louisiana. The six interior domes in Texas are described in detail below. There are many other salines in eastern Texas which are not salt domes. Northern Louisiana has thirteen known domes and has many more salines which ap-

FIG. 1.—Outline map of Texas, Louisiana, Arkansas, and Oklahoma showing relationship of coastal and interior salt domes (dots) to the Sabine and Monroe uplifts (as outlined by Upper Cretaceous structure contours), and to other structural features.

The present Wichita Mountains are extended to include the amarillo arch on the west and the Red River arch–Healdton and Criner Hills buried flanks on the east. The Arbuckle Mountains are extended southeastward by new discoveries and the Sabine uplift as outlined in Lower Cretaceous strata, with northwest-southeast axis is a buried part of the Arbuckle line of folding. The Monroe uplift may be another parallel, buried Paleozoic ridge of pre-Ouachita Mountains generation. The "Granite Ridge" (Nemaha Mountains) and Bend arch may represent a line of Mississippian continental fracture whose counterpart is found in the Balcones and Mexia fault zones.

pear not to be salt domes. The scarcity of exposures and the lack of wells render the classification of many salines difficult. Three salt domes were discovered in northern Louisiana by geologists in 1922. Other domes will undoubtedly be found in the same general area. A question has been raised concerning the origin of the large structural domes on which the Homer and Bellevue fields are located,

but these folds embrace many square miles whereas the proved salt domes cover only about three square miles each. The larger folds seem to be the expression of tangential compression accentuated, possibly, by buried hills.

EXAMINATION

The interior domes of Texas were first described in the first, second, and third annual reports of the Texas Geological Survey under the direction of Mr. E. T. Dumble.[1] The next series of reports by O. B. Hopkins, by E. DeGolyer, and by the writer,[2] form the basis for the present paper which is largely a résumé of the literature. The writer has visited each of these domes several times since the summer of 1916 and desires to emphasize the wealth of information regarding physiography and geology which could be amassed by intensive study of each of them. A number of other geologists have made private reports on one or more of the domes and the reports of Alexander Deussen and L. C. Chapman have been used in the preparation of this paper. The writer is indebted for information to Alexander Deussen, Wallace E. Pratt, Dr. L. W. Stephenson, and Dr. Julia A. Gardner, and, for many courtesies, to M. A. Davey, of Palestine, Texas. Miss L. L. Lane, of the Marland Oil Company of Texas, Miss A. C. Ellisor, of the Humble Oil and Refining Company, Miss H. T. Kniker, formerly of the Texas Company, A. L. Selig and F. X. Bostick of Shreveport, Louisiana, have very kindly identified micro-faunas from several of the domes as well as from the normal outcrop of the same formations.

The Louisiana interior domes were described in detail by Veatch[3] and later by Harris[4] and are being described by W. C. Spooner in a paper of this series in the *Bulletin*.

[1] Detailed references are given in the more recent reports.

[2] O. B. Hopkins, "The Palestine Salt Dome (and Keechi Salt Dome), Anderson Co., Texas," *U. S. Geol. Surv. Bull. 661G*, 1917; E. DeGolyer, "The West Point Salt Dome, Freestone Co., Texas," *Jour Geol.* Vol. 27, 1919, pp. 647-63; Sidney Powers and O. B. Hopkins, "The Brooks, Steen, and Grand Saline Salt Domes, Smith and Van Zandt Counties, Texas," *U. S. Geol. Surv. Bull, 736G*, 1922. Also C. A. Cheney, "Salt Domes of Northeastern Texas," *Oil and Gas Jour.*, January 6, 1922, p. 82, reviewed by K. C. Heald, *Amer. Assoc. Petroleum Geologists Bull.*, Vol. 6, 1922, p. 58.

[3] A. C. Veatch, "Geology and Underground Water Resources of Northern Louisiana and Southern Arkansas," *U. S. Geol. Surv., Professional Paper 46*, 1906.

[4] G. D. Harris, "Oil and Gas in Louisiana," *U. S. Geol. Surv. Bull. 429*, 1910.

References are omitted from the text because the present paper is a recapitulation of those already cited. Errors in previous papers have been corrected without explanation. Bulletin 736 of the United States Geological Survey is referred to several times in the text. Maps accompanying the reports of the U. S. Bureau of Soils in Smith, Anderson, and Freestone counties show the drainage around these domes.

EXPLOITATION

During the Civil War many of the interior salt domes were exploited for salt and they were one of the most important sources of this commodity available to the South. Steamboat boilers cut through the center longitudinally served as kettles in Louisiana. Salt manufacture by white settlers began, however, much earlier—in 1805 in Louisiana, in 1835 in Texas—but it practically ceased after the Civil War. Salt is now mined at two domes in Texas by means of wells 450 to 500 feet deep. Casing is landed in the cap rock overlying the salt and water is either allowed to run down from upper sands or is pumped down to the salt and in either case is pumped up into evaporating pans in the plants. Steam evaporation was introduced in Texas about 1886.

Salt was evaporated during the Civil War in Louisiana, at Bistineau, King, Rayburn, Drake, and Cedar salines; in Texas at Grand Saline, Steen, Brooks, and Palestine salines. Salt has been mined for many years at Grand Saline and at Palestine saline.

Limestone has been quarried, principally for the manufacture of lime, at the Winnfield marble quarry and at Pine Prairie salt dome, Louisiana, and at Steen and Brooks salines, Texas. The limestone at Winnfield and Pine Prairie is cap rock and has been extensively quarried for a number of years. Calcareous sandstone was quarried for a short time at Steen saline, but the percentage of lime was too small. The Austin chalk furnished excellent lime at Brooks saline during the Civil War.

Sulphur is practically unknown in the interior domes, although it is exploited in several coastal domes.

Neither oil nor gas has been found in commercial quantities in any interior salt dome with the possible exception of the showing of heavy oil at Keechi. Only two Texas domes, Brooks and Keechi,

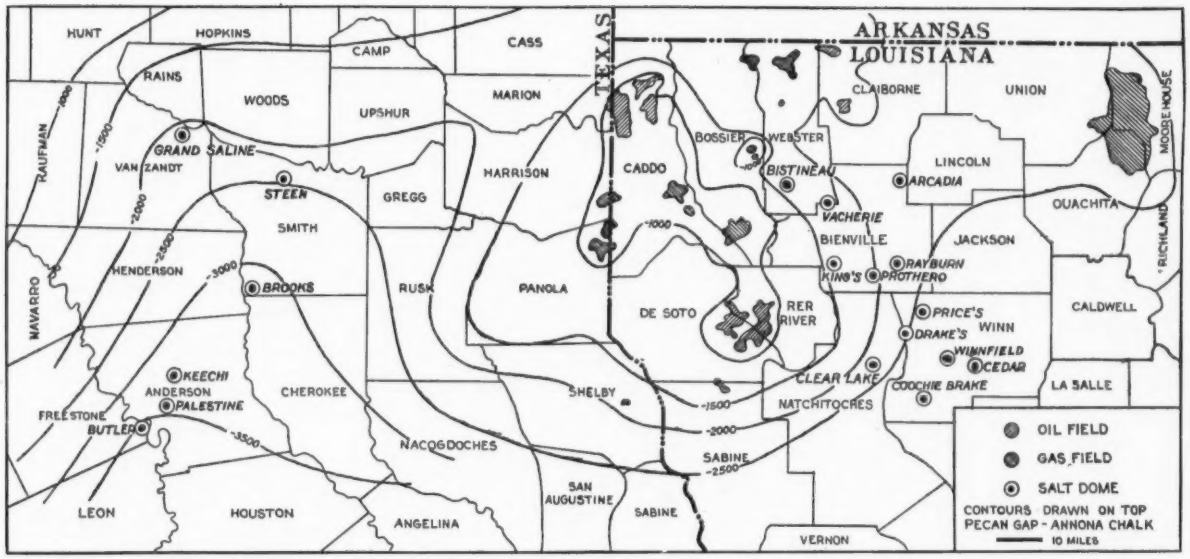


FIG. 2.—Subsurface structure contour map of eastern Texas and northern Louisiana contoured on the top of the Pecan Gap and Annona chalks (assuming them lithologically continuous).

Contours are below sea-level with intervals of 500 feet ignoring faults. The interior salt domes are near the axis of the eastern Texas geosyncline and on the eastern flank of the Sabine uplift. The areal distribution of the Wilcox and Claiborne is shown by broken lines. Contours in Louisiana modified from manuscript map of W. C. Spooner.

have been tested and neither of them has been condemned except in very limited areas. A number of wells are required to condemn a salt dome. The outline of the salt core is seldom as regular as indicated by surface topography and geology, and wells are drilled unexpectedly into salt. The sides of the dome plunge sharply and may be squeezed or faulted so that wells miss a normal section. The supposition that the oil disappeared at the time of the salt intrusion is not supported by facts; Vacherie and Arcadia salt domes Louisiana, are completely covered by sands which produce oil elsewhere, but salt water only on these domes.

Production may be obtained in any of a number of sandy horizons in the Upper Cretaceous and wells should be carefully drilled, cored at each change of formation, and the cores examined microscopically for fossils to determine the stratigraphic horizon. The oil possibilities of eastern Texas invite exploration.

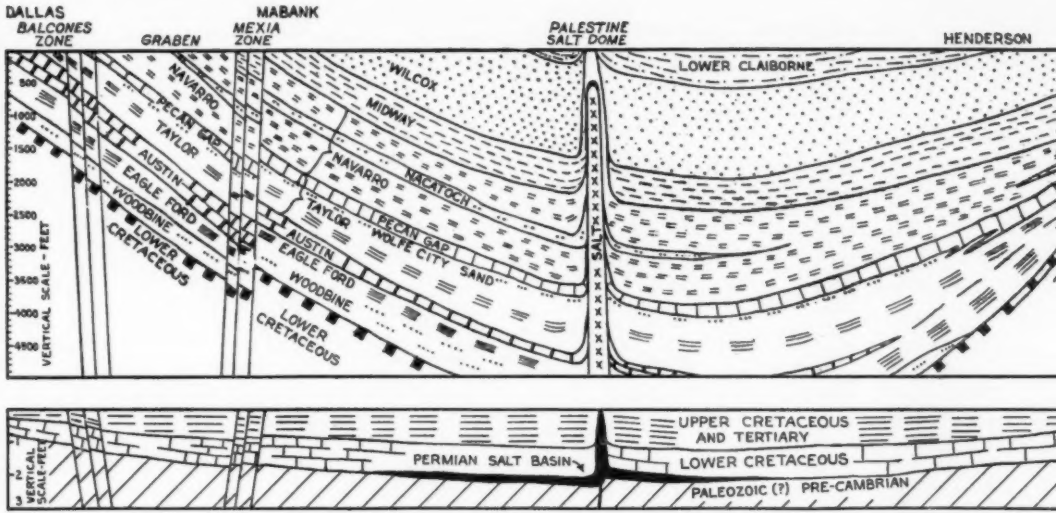
GEOLOGY

STRATIGRAPHY

The interior salt domes of Texas and Louisiana north of the outcrop of the Oligocene are confined to the outcrops of the Wilcox and Claiborne groups, both of Eocene age, but wells have been drilled through the Upper Cretaceous and into the lower group of the Lower Cretaceous. Formation names change at the Texas-Louisiana line. The formations themselves thicken and thin and change both in lithologic character and in age.

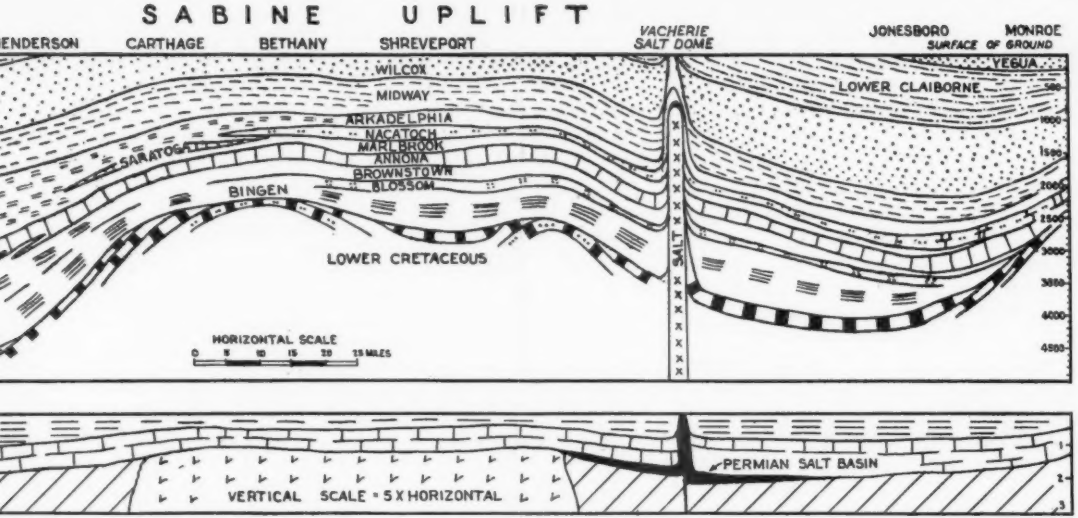
Geologic subdivisions according to age equivalence are given in Table I.[1] The thicknesses of formations change as shown in Plate 1 and estimates are given for the section at each salt dome in the description of the dome. Formations on the eastern side of east

[1] These are taken from the following sources: G. D. Harris, "Oil and Gas in Louisiana," *U. S. Geol. Surv. Bull. 429*, 1910; Alexander Deussen, "Geology and Underground Waters of the Southeastern Part of the Texas Coastal Plain," *U. S. Geol. Surv. Water Supply Paper, 335*, 1914; E. T. Dumble, "The Geology of East Texas," *Univ. of Texas Bull. 1869*, 1918; L. W. Stephenson, "A Contribution to the Geology of Northeastern Texas and Southern Oklahoma," *U. S. Geol. Surv. Professional Paper 120H*, 1918; *Prof. Paper 81*, 1914, Pl. 12. Also A. C. Ellisor, *Amer. Assoc. Petroleum Geologist Bull.*, Vol. 9, 1925, and W. C. Spooner, *Monroe Gas Field, Louisiana*. Dept. of Conservation, Shreveport, 1926.



CROSS-SECTIONS OF EASTERN TEXAS AND NORTHERN LOUISIANA CONSTRUCTED FROM WELL LOGS TO SHOW TI

Correlations of formations are tentative. The vertical scale of the upper section is greatly exaggerated, that of the lower sec
Monroe uplifts underlain by pre-Cambrian rocks (granites?) more resistant to erosion than those elsewhere (schists?) underlying



S TO SHOW THE THICKENING OF FORMATIONS ON EACH SIDE OF THE SABINE UPLIFT AND ESPECIALLY IN TEXAS

the lower section is five times the horizontal. The lower section shows salt domes arising along fracture lines and the Sabine and) underlying the Coastal Plain. Hypothetical Permian salt basins of local extent are shown.

Texas are more similar to those in Louisiana than to those in central Texas and are best designated with their Louisiana names.

In Louisiana, Coochie Brake, Winnfield, and Cedar Creek salt domes are in the belt of outcrop of the Yegua (Fig. 2), the others in that of the St. Maurice. In Texas, Grand Saline dome is entirely within the Wilcox, the others are near the outcrop of the base of the Mount Selman formation.

TABLE I

	Central Texas	Eastern Texas	Northern Louisiana
Eocene	Claiborne group Yegua formation Cook Mountain formation Mount Selman formation	Claiborne group Yegua formation Cook Mountain form. Mount Selman form.	Claiborne group Yegua (Cockfield) form. St. Maurice form. Sparta sand* Cane River*
	Wilcox group Carrizo sandstone Indio formation	Wilcox group Carrizo sandstone Indio formation	Wilcox formation
	Midway formation	Midway formation	Midway formation
Upper Cretaceous	Navarro formation	Arkadelphia clay Nacatoch sand Unnamed shale	Arkadelphia clay Nacatoch sand
	Taylor marl	Pecan Gap chalk Wolfe City sand Annona tongue	Marlbrook marl (including Saratoga chalk) Annona chalk Brownstown marl
	Austin chalk	Blossom sand Unnamed clay and sand (including Ector chalk)	Bingen group
	Eagle Ford clay Woodbine sand	Eagle Ford formation Woodbine sand	Unconformity
Lower Cretaceous		Washita group Fredericksburg group Trinity group	Washita group Fredericksburg (locally absent) Trinity group
Pennsylvanian (?)			
Permian (??)			
Pre-Cambrian			

* New formation names introduced by W. C. Spooner in manuscript.

There are adequate published descriptions of formations in Texas[1] except for the Wilcox, which has been made into a group of two or more formations, and the Austin and Annona chalks, the ages of which are not positively determined.

The Wilcox in east Texas consists of lignitic sandy shales below and sands above. The lower part has been called the Lignitic[2] and

[1] Descriptive sections from well logs are given by F. Julius Fohs, "Structural and Stratigraphic Data of Northeast Texas Petroleum Area," *Econ. Geol.*, Vol. 18, 1923, Pl. 13.

[2] E. T. Dumble, *Univ. of Texas Bull. 1869*, 1918, p. 37.

the Indio[1] but the former term has suffered so many redefinitions that the latter is accepted. The upper part has been called the Carrizo sandstone in southwestern Texas and the Queen City sand in eastern Texas and has been placed in the Claiborne group until recently. The more widely accepted term Carrizo is used instead of Queen City.[2] The Indio formation has yielded plant remains of Lower Wilcox age,[3] foraminifera and ostracods, both above and below lignite beds[4]—in more localities than have been published—and, in southwestern Texas, a fauna of lower Wilcox age.[5] The Carrizo sandstone in southwestern Texas has yielded plant remains of upper Wilcox age and at Sabinetown[6] and, possibly, at Palestine salt dome a fauna of upper Wilcox age.

A division of the Wilcox is difficult to map except in limited areas and is not attempted in the detailed maps of the salt domes. The top of the Wilcox is likewise difficult to determine, and the boundaries in Figure 2 are taken from previous publications.[7]

Confusion of chalks has arisen because at least three are exposed at the outcrop in one county (Fannin): the Pecan Gap chalk member of the Taylor Marl, and the Ector tongue and Annona tongue of the Austin chalk. At least two chalks, the Pecan Gap and Austin, are recorded in well logs as far east as Cherokee County. In east central Texas both may carry a Taylor fauna, though not the same fauna, and in northern Louisiana the Annona chalk carries a Taylor

[1] A. C. Trowbridge, "A Geologic Reconnaissance in the Gulf Coastal Plain of Texas Near the Rio Grande," *U. S. Geol. Surv. Professional Paper 131D*, 1923; Alexander Deussen, "Geology of the Coastal Plain Region of Texas West of the Brazos River," *U. S. Geol. Surv. Professional Paper 126*, 1924.

[2] Wm. Kennedy, "The Eocene Tertiary of Texas East of the Brazos River," *Acad. Nat. Sci. Proc. for 1895, 1896*, p. *135*; *Geol. Surv. of Texas, Third Ann. Rept.*, 1892, p. 50; Alexander Deussen, *U. S. Geol. Surv. Water 1914*, p. 44.

[3] E. T. Dumble, *op. cit.*, p. 40; E. W. Berry, *U. S. Geol. Surv. Professional Papers 91H*, 1916, *131A*, 1923, *132E*, 1925.

[4] A. C. Trowbridge, *op. cit.*, p. 90.

[5] Julia A. Gardner, "Fossiliferous Marine Wilcox in Texas," *Amer. Jour. Sci.*, Vol. 7, 1924, pp. 141–45.

[6] G. D. Harris, *Geol. Surv. of La., Report for 1898*, p. 67.

[7] G. D. Harris, *U. S. Geol. Surv. Bull. 429*, 1910; W. C. Thompson, "The Midway Limestone of Northeast Texas," *Amer. Assoc. Petroleum Geologists Bull.*, Vol. 6, 1922, p. 326; F. Julius Fohs, *op. cit.*, Pl. 12; Alexander Deussen, *U. S. Geol. Surv. Water Supply Paper 335;* E. T. Dumble, *Univ. of Texas Bull., 1869.*

fauna. The upper part of the Annona in Louisiana (the *Ananchytes* zone of White Cliffs, Arkansas) is paleontologically and lithologically the equivalent of the Pecan Gap of Texas and the lower part is equivalent to the lower part of the Pecan Gap or to associated chalk lentils. The paleontological equivalent of the Austin chalk in Louisiana may be the Blossom sand and part of the Brownstown; the chalk itself is believed to lens out in Rusk County. The so-called "Woodbine" oil sands in Louisiana were thought to occur in and above the Eagle Ford and not to be equivalent to the Woodbine sand of Texas,[1] but recent determinations by F. X. Bostick place them under the Buda limestone of Lower Cretaceous age on the Caddo Uplift.[2]

A remarkable thickening of the stratigraphic section in east Texas is found from the middle of the Claiborne group through the beds of Taylor age, the lowest available for study, as shown in the cross-section, Plate I. The greatest thickening appears to be in the Wilcox and in the Taylor. Other formations can seldom be delimited in well logs.

GEOLOGIC HISTORY

Geologic history in the Gulf Coastal Plain is shrouded in the ancient and obscure Llanoria,[3] a fragment of which is visible in the Llano-Burnett horst of central Texas. Wells east of, but close to this horst find pre-Cambrian schist or Cretaceous igneous rocks. Wells at Fort Worth and on the Preston anticline find Pennsylvanian shales beneath the Cretaceous. Wells elsewhere in the Coastal Plain except in Cooke, Grayson, and Denton counties and along the Red River in Lamar and Red River counties, Texas, have not gone through the Lower Cretaceous, but those which have reached older rocks indicate that the Sabine uplift is a portion of the Arbuckle Mountains uplift of Middle Pennsylvanian and Permian age (Fig. 1).[4]

[1] G. C. Matson and O. B. Hopkins, "The De-Soto-Red River Oil and Gas Field, Louisiana," *U. S. Geol. Surv. Bull. 661*, p. 115; W. M. Winton and Gaylor Scott, "The Geology of Johnson Co., Texas," *Univ. of Texas Bull. 2229*, 1924, p. 31.

[2] Personal communication, September, 1925, from Mr. Bostick.

[3] H. D. Miser, "Llanoria," *Am. Jour. Sci.*, Vol. 2, 1921, pp. 61–89.

[4] The writer postulates a buried extension of the Wichita Mountains with the "Red River arch" on the south flank and the Healdton-Criner hills on the north flank and a buried extension of the Arbuckle Hills to connect with or include the Sabine uplift,

Red potash salt was discovered by the Rycade Oil Corporation on the Markham Texas salt dome in 1924[1] and red algae from this salt have been identified by Professor Josephine E. Tilden of the University of Minnesota as *Phormidium antiquum* n. sp. identical with red algae collected by the writer in the Permian salt mine at Kanopolis, Kansas.[2] This discovery is the first positive evidence of the Permian age of the Gulf Coast salt, but nothing is known regarding associated sediments and possible local Permian basins between the truncated mountain ranges of Llanoria were not connected with the Permian basin of western Texas.

Professor Charles Schuchert writes concerning the algae as follows:

> It is clear what you have discovered, but the fact that the same apparent species of algae occur in the Permian salt of Kansas and in the salt of a salt dome of Texas does not prove at all that both salts are of the same age. Algae are such long-lived plants, and the fossil ones preserve so little of their original structures, that I think one should be cautious about saying that, on the basis of algae, the salt of the salt domes of Texas is to be correlated with the Permian. We need something in the way of fossils that is more dependable than algae, to determine the age of the salt in the Texas salt domes.[3]

Coastal Plain sedimentation as known from outcrops started in Lower Cretaceous time and Dumble[4] has called attention to the fact that the Trinity carries gypsum in Arkansas and in West Texas. Gypsum and anhydrite are also found in thick beds in the Lower Cretaceous in the Pine Island oil field, Louisiana. The Trinity is locally red in southern Oklahoma and it may contain some salt.

Lower Cretaceous sediments consisted of sand and sandy shale at the base overlain by limestone and shale, limestone being very

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marked by the Bailey Development Company well in northern Lamar County with schist at 1,880 feet and the Lady Alice well in northern Red River County, Texas, with schist at 1,673 feet south of a deep Lower Cretaceous trough proved by wells in sec. 2, T. 13 S., R. 31 W., 3,363 feet deep, and in sec. 15, T. 13 S., R. 29 W., 3,780 feet deep, Little River County, Arkansas, both of which stopped in Lower Cretaceous.

[1] E. DeGolyer, "Discovery of Potash Salts and Fossil Algae in Texas Salt Dome," *Am. Assoc. Petroleum Geologists Bull.*, Vol. 9, 1925, pp. 348–49.

[2] Personal communication from Professor Tilden.

[3] Letter, October 5, 1925.

[4] E. T. Dumble, *Amer. Inst. Min. Engrs. Bull. 143*, 1918, p. 1634.

abundant. The Lower Cretaceous has been divided into three groups of formations of which the Trinity at the base has become of great economic importance since the discovery of oil and gas in the Glen Rose formation on the Sabine uplift. This uplift is now proved to have existed as early as middle Lower Cretaceous time because the Trinity sediments are relatively steeply folded in the Pine Island oil field, and are unconformably overlain by gently folded sediments of the Washita group, the Fredericksburg group being absent. The "Woodbine" oil sands and red shales of the Washita group may represent another period of uplift and the absence of the Woodbine formation of Texas indicates a period of erosion after deposition of the Buda limestone.

Upper Cretaceous sediments rest unconformably on the older series and overlap them in Arkansas. The younger series consists of Eagle Ford shales at the base overlain by marls and shales with one or more chalk horizons. Another disconformity separates the Upper Cretaceous from the marine Midway formation of the Eocene which contains limestone in east Texas. A largely non-marine sandy phase, the Wilcox group, follows the long succession of marine strata. The Wilcox is disconformable on the Midway and overlaps it in Arkansas. The lower part of the Wilcox does not cover the Sabine uplift.[1] Eocene sediments in the Eastern Texas geosyncline are thicker than in the corresponding Louisiana geosyncline. Renewed uplift took place at least as early as the beginning of Wilcox time. The Claiborne group of sediments lies disconformably upon the Wilcox group and the complete Claiborne series was probably never deposited on the Sabine uplift. This uplift took the form of an enormous terrace with a north-south axis, but did not assume its present outline until later because younger sediments are more steeply tilted south of it than in the geosynclines on either side.

The interior salt domes of Louisiana and Texas have had similar life histories. The salt was derived from the same horizon in Permian sediments. The domes commenced growing by salt flowage at the same time probably in the Lower Cretaceous, according to Spooner, and may have had later contemporaneous periods of

[1] Personal communication from W. C. Spooner. Locally the hiatus is greater than shown by Berry (*U. S. Geol. Surv., Professional Paper 132 E*, 1924).

growth. Uplift was not pronounced until late in Wilcox sedimentation and then only in Texas where the Wilcox is steeply tilted wherever exposed on the flanks of the domes. The Claiborne beds show less tilting. Growth of the domes did not permanently cease, however, until after the Claiborne sediments were deposited because they are uplifted in several Louisiana domes. Whether or not uplift continued into the Oligocene as in the semi-interior domes, Brenham, in Texas and Pine Prairie in Louisiana, or even into more recent time, is uncertain, but possible.[1]

Dome formation was probably initiated by deep seated faulting corresponding to the shearing visible in the Tahlequah (Ozark) uplift and in the Pennsylvanian sediments in Oklahoma and also exposed in the pre-Cambrian of the Llano-Burnet region. It was genetically connected with the movements which brought about the formation of the Sabine uplift, the corresponding Llano-Burnet horst, and the Balcones and Mexia fault zones and intervening graben and other lines of faulting yet to be discovered. These movements were the breaking down of the Coastal Plain with a shearing stress which created fault zones—or rejuvenated old lines of weakness according to Dr. Udden.[2]

A second period of folding affected the salt domes and the Sabine uplift. It followed the deposition of the Claiborne group and preceded the deposition of the Oligocene. The compression was from north to south, or, more exactly, from north-northwest to south-southeast, forming the cross axes and domes on the Sabine uplift and the other numerous domes and anticlines of northern Lousiana and northeastern Texas and defining both the Sabine and Monroe uplifts in their present form.[3] Faulting, as revealed at Homer, Bull Bayou, Stephens, Irma, Smackover, and elsewhere accompanied this movement.

[1] Charles Schuchert (Discussion of paper by DeGolyer, *Amer. Assoc. Petroleum Geologists Bull.*, Vol. 9, 1925, p. 872) suggests that the salt domes are due to faulting of Llanoria during Cenozoic times and chiefly previous to the Miocene. The coastal domes were intruded after Jackson time and the earlier Oligocene sediments pinch out against them.

[2] J. A. Udden, *Amer. Inst. Min. Engrs. Trans.*, Vol. 57, 1918, p. 1086.

[3] Sidney Powers, "The Sabine Uplift, Louisiana," *Amer. Assoc. Petroleum Geologists Bull.*, Vol. 4, 1920, pp. 117–36. The mechanics of the faulting is discussed by Heath Robinson, *Econ. Geol.*, Vol. 18, 1923, pp. 722–31.

Volcanic activity started in northern Louisiana and southern Arkansas near the close of the Lower Cretaceous with a great thickness of tuffs and other ejectamenta which have been found in one well in the Monroe gas field[1] and in the outcrop of the Bingen formation in Arkansas and Oklahoma. Active volcanoes were numerous near Murfreesboro, Arkansas, and Uvalde, Lockhart, Thrall, and north of Spofford, Texas, and in the Burro Mountains, Mexico, during Taylor sedimentation. Volcanoes in west Texas showered a large part of Texas with ashes in Jackson (Frio), Eocene time. This volcanic activity does not have a proved connection with the salt domes.

COMPARISON OF INTERIOR DOMES OF TEXAS AND LOUISIANA

TABULATION

Table II summarizes the most important characteristics of the recognized interior domes.

TOPOGRAPHY

Physiographic expression of interior salt domes may take one of several types depending largely upon the proximity of the salt to the surface and to the amount of uplift of the formation normally at the surface. The surface manifestations of interior salt domes are as follows: (1) saline prairies or salt licks; (2) lakes with or without surface outlet, often fed by circular drainage; (3) springs or water wells usually slightly mineralized; (4) circular drainage system around a central hill or around a circular row of hills within which lies a saline prairie or lake; (5) exposures of tilted rocks; (6) exposures of cap rock or of formations older than those normally found in the region; (7) cap rock, salt, or rock of formations normally deeply buried found at shallow depths in wells; (8) soils of unusual nature which may contain calcite crystals or other vein-forming minerals with or without slickensides.

Saline prairies not connected with salt domes are found throughout the Gulf Coastal plain[2] and their origin is connected with the

[1] The Palmer Trust well in SE. cor. NE. ¼, sec. 3, T. 18 N., R. 5 E., found volcanic rock from 2,221 to 3,427 feet underlain by Lower Cretaceous (Washita?) sediments. M. N. Bramlette, *Amer. Assoc. Petroleum Geologists Bull.*, Vol. 8, 1924, pp. 342–46. Also, A. F. Crider, "Volcanic Ash in Northern Louisiana," *ibid.*, p. 524.

[2] These are mapped by G. D. Harris, "Oil and Gas in Louisiana," *U. S. Geol. Surv. Bull. 429*, 1910, Pl. 12; they are described by E. T. Dumble, "The Geology of East Texas," *Univ. of Texas, Bull. 1869*, 1920, p. 309.

TABLE II

Salt Dome	Salt Core					Cap Rock		Saline, "Licks", or Lake		Wells		Geology		Amount Uplift Strata	Diameter Area Uplifted
	Found	Shallowest Known Depth Feet	Top Eroded	Diameter Miles	Mined During Civil War	Found	Depth Feet	Central	Circular around Central Hill	Deepest on Top Dome	Deepest on Side Dome	Normal Surface Formation	Oldest Formation Cropping Out	Feet	Miles
Texas															
Grand Saline	X	235	Yes	1½	Yes	X	188	X	.....	520	3,842	Wilcox	Wilcox	500	2½
Steen	X	300?	Yes	1	Yes	X	75	X	.....	600?	2,630	Mt. Selman	Wilcox	500	3
Brooks	X	220	Yes	1½	Yes	X	195	X	.....	429	3,193	Mt. Selman	Austin	4,300	3
Keechi	X	2,162	?	1	No	No	.....	.....	.....	3,170	3,048	Mt. Selman	Taylor	3,500	3½
Palestine	X	122	Yes	¾	Yes	X	120?	X	.....	700	.....	Mt. Selman	Buda	5,500	4½
Butler	X	312	?	1¼	No	?	.....	X	X	1,200	1,220	Wilcox	Navarro	2,500	3½
Louisiana															
Bistineau	X	1,862	Yes	1½	Yes	X	1,420	X	.....	2,305	3,245	St. Maurice	Marlbrook	1,500	4
Vacherie	X	777	No	1×1½	No	X	658	X	.....	897	2,558	St. Maurice	Arkadelphia	1,500	3×4
Arcadia	X	1,400	No	1	No	X	1,375	X	.....	4,012	3,450	St. Maurice	Arkadelphia	2,350	4
Rayburn	X	115	Yes	¾	Yes	X	At surface	X	.....	277	3,003	St. Maurice	Blossom	2,200?	3
King's	X	175	Yes	1	Yes	X	160	X	.....	136	2,225	St. Maurice	Marlbrook	2,000	3
Price's	X	1,300?	?	¾	Yes	X	1,100?	.....	X	None	?	St. Maurice	Wilcox	1,500	2
Prothero	.....	.....	?	1×1½	No	No	.....	X	.....	None	None	St. Maurice	Blossom	3,000	2½
Drake's	X	900	Yes	1	Yes	X	290	X	.....	2,312	1,510	St. Maurice	Wilcox	1,500	2½
Winnfield	X	999	No	1½	No	X	At surface	X	.....	1,110	4,021	Cockfield	Wilcox	2,000	2½
Cedar Creek	.....	.....	?	1	Yes	X	801	X	.....	700	3,150	Cockfield	St. Maurice	1,500	3
Coochie Brake	.....	.....	.....	1	No	No	.....	X	.....	None	3,100	Cockfield	St. Maurice?	1,500	2½
Clear Lake	X	234?	?	1	No	?	.....	X	.....	.....	3,463	Cockfield	St. Maurice	1,500?	2½
Gibsland	.....	1,238	.....	.....	No	X	1,142	.....	.....	1,520	.....	St. Maurice	.....	1,000	2

The location of the Louisiana domes is as follows: Bistineau, secs. 35, 36, T. 18 N., R. 10 W.; Vacherie, sec. 16, T. 17 N., R. 8 W.; Arcadia, sec. 29, T. 18 N., R. 5 W.; Rayburn, sec. 31, T. 15 N., R. 5 W.; King's, secs. 34, 35, T. 15 N., R. 8 W.; Price's, sec. 30, T. 13 N. R. 4 W., and sec. 25, T. 13 N. R. 5 W.; Prothero, secs. 7, 8, 17, 18; T. 14 N., R. 6 W.; Drake, secs. 20, 21, T. 12 N., R. 5 W.; Winnfield sec. 19, T. 11 N., R. 3 W.; Cedar Creek, secs. 30, 31, T. 11 N., R. 2 W.; Coochie Brake, sec. 6, T. 9 N., R. 4 W.; Clear Lake, secs. 28, 29, 32, 33, T. 11 N., R. 6 W.; Gibsland, sec. 15, T. 18 N., R. 7 W. (Discovered December 1925).

presence near the surface of rocks containing small quantities of salt or with normally shallow connate salt water brought to the surface along joints and fault planes. Sufficient salt is found in this water to permit salt manufacture by evaporation. Excellent exposures of rock with normal dip are found near some of these salines.

Springs and small mounds[1] are characteristic of salt domes. If the salt is near the surface, salt water issues in salines and "licks" and furnishes the salt evaporated at a number of domes during the Civil War. Sulphur, alum, and other mineralized springs are common and deserve more attention than has been devoted to them.

COMPOSITION

All interior domes are cylindrical plugs over a mile in height with a diameter within 3,000 feet of the surface of ½ mile to 1½ miles. At Grand Saline the top of the core of salt was found in one well at 306 feet and in a well ¼ mile away the salt was not reached at 3,842 feet. The salt core is so nearly cylindrical that wells which enter salt seldom find either sedimentary rock or cap rock beneath. In places wells find alternating beds of salt and shale or cap rock, or else stringers of salt.

The tops of most interior salt domes have been eroded and the

[1] The origin of the small mounds is a mooted point because different mounds are formed from different causes. The following is an incomplete list of references discussing their origin:

A. C. Veatch, *U. S. Geol. Surv. Professional Paper 46*, 1906, p. 55.

M. R. Campbell, "Natural Mounds," *Jour. Geol.*, Vol. 14, 1906, pp. 708–17 (Bibliography).

J. A. Udden, "The Origin of Small Sand Mounds in the Gulf Coast Country," *Science, U. S.*, Vol. 23, 1906, p. 849.

W. H. Hobbs, "Some Topographic Features Formed at the Time of Earthquakes and the Origin of Mounds in the Gulf Coastal Plain," *Amer. Jour. Sci.* (4), Vol. 23, 1907, p. 245.

C. H. Gordon, *U. S. Geol. Surv. Water Supply Paper 276*, 1911, p. 32.

G. C. Matson, *U. S. Geol. Surv. Bull. 519*, 1916, p. 12.

William Kennedy, *Southwestern (Amer.) Assoc. Petroleum Geologists Bull.*, Vol. 1, 1917, p. 41.

E. G. Woodruff, *ibid.*, p. 81.

G. S. Rogers, *Amer. Inst. Min. Engrs. Bull. 136*, 1918, p. 285.

R. T. Hill, *Dallas Morning News*, October 2, 1919.

Sidney Powers, *Amer. Jour. Sci.* (4), Vol. 49, 1920, p. 132.

T. L. Bailey, *Univ. of Texas Bull. 2333*, 1924, pp. 22–30 (cites example of mound 20 feet in diameter which has risen under a house).

surface of the salt is reached at from 200 to 300 feet. The surface of the salt where thus eroded is horizontal and the overlying sediments are probably in part secondary wash deposits.

The salt in salt domes is very pure sodium chloride (96–99 per cent) and is similar to that in bedded deposits.[1] The colorless salt is streaked with black bands as in bedded deposits of Kansas, but these are contorted and squeezed by the intrusion of the salt plug so that a photograph of the salt resembles one of schist.[2] The streaks, according to Harris,[3] "are not caused by any dark substance in the salt, but by the absorption of the rays of light by minute particles of seemingly clear anhydrite. This is proved first by dissolving some of the streak salt in fresh water and noting the 'sand,' as the miners say, that settles at the bottom." He gives the following analyses of salt from Avery's Island to substantiate his conclusions:[4]

	Colorless Salt	Black Salt
Na Cl	99.10	96.53
H_2O	.10	.20
Water insoluble Ca SO_4	.23	2.16
Water soluble Ca SO_4	.33	1.05
	99.76	99.94

Veatch states that "the black salt on Petite Anse (Avery's Island) shows about seven per cent of insoluble matter, part of which is gypsum and the Belle Isle black salt shows about the same amount of insoluble matter, part of which, although a much smaller amount, is gypsum."[5] Black streaks in bedded deposits may also be caused by interbedded shales or clay or organic matter.[6] The only other

[1] Chemical analyses may be found in the reports by Harris and by Veatch, cited below, and in *U. S. Geol. Surv. Bulls. 669, 695, 736G;* and in A. W. Grabau, *Geology of the Non-Metallic Mineral Deposits Other Than Silicates*, Vol. 1, *Principles of Salt Deposition*, New York, 1922.

[2] G. S. Rogers, "Intrusive Origin of the Gulf Coast Salt Domes," *Econ. Geol.*, Vol. 13, 1918, p. 468.

[3] G. D. Harris, "Louisiana," *Geol. Surv. Bull. 7*, 1908, p. 7.

[4] *Ibid.*, p. 16.

[5] A. C. Veatch, "The Five Islands," *Louisiana Geol. Surv. Report for 1899*, p. 226.

[6] W. C. Phalen, Personal Communication; also, *Science, U. S.*, Vol. 55, 1923, pp. 479–80.

known impurities in the salt of salt domes is a very small amount of sandstone, colored red by hematite in the Avery's Island Mine.[1] Red salt containing sylvite has been found on the flank of only one salt dome—Markham.

Cap rocks are very thin shells in the case of most eroded cores. There is cap rock in the center of the dome and the cap on the side increases in thickness as the edge of the dome is reached. The thickness varies from a few to 50 feet. At Winnfield marble quarry, Louisiana, the cap rock is exposed at the surface and is 1,000 feet thick. Cap rock may be found interfingered with the sedimentary rocks as in the Tampico Oil Company's well at Winnfield and more rarely with the salt. The cap rock is in general a thimble confined to the top of the dome and is apparently formed and replaced after the core stops growing. Cap rock may be formed at the end of each period of renewed growth of the dome and apparently this has been the case at Winnfield.

The composition of cap rock is usually anhydrite, gypsum, limestone, or sulphur as described by Goldman.[2] The cap rock of the interior domes of Texas, where known, is limestone.

GRAND SALINE SALT DOME

LOCATION, HISTORY, AND SALT PRODUCTION

Grand Saline, formerly called Jordan's saline, was Cherokee Indian land and is near the northern end of the Spanish land grants. It is located in northeastern Van Zandt County on the Samuel Bell survey. The town of Grand Saline is situated on the northern rim of the dome and the Texas and Pacific Railroad crosses the north side of it. Sabine River is 4 miles northeast of the dome.

Salt was evaporated by the Indians and later by the white settlers starting in 1845. Fred Ham installed the first kettles in 1853 and sold the land to S. Q. Richardson in 1859 who put in a more elaborate plant, a pump operated by a

[1] G. S. Rogers, *ibid.*, p. 471.

[2] M. I. Goldman, "Petrography of Salt Dome Cap Rock," *Am. Assoc. Petroleum Geologists Bull.*, Vol. 9, 1925, pp. 42–78. *See* also, E. DeGolyer, "Origin of the Cap Rock of the Gulf Coast Salt Domes," *Econ. Geol.*, Vol. 13, 1918, pp. 616–20; C. W. Washburne, "Oil Field Brines," *Amer. Inst. Min. Engrs. Bull. 164*, 1920, pp. 3–13; E. DeGolyer," "Origin of North American Salt Domes," *Am. Assoc. Petroleum Geologists Bull.*, Vol. 9, 1925, pp. 831–74.

mule and a pipe line of hollowed wooden logs.[1] It was visited by the Army of the Republic of Texas under Gen. K. H. Douglas on July 18, 1839.

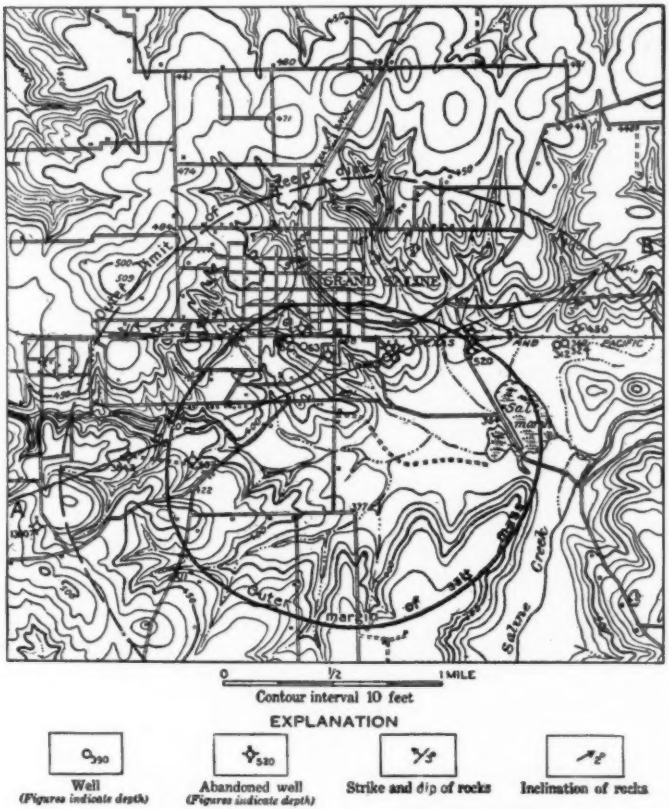

FIG. 3.—Topographic map of Grand Saline salt dome reproduced from *U. S. Geol. Survey Bulletin 736*. The figures at the side of wells refer to their depth. The wells nearest to the railroad station both east and west are salt wells. This dome is an excellent illustration of the physiographic type of dome with a central saline surrounded by hills.

During the Civil War evaporation of salt took place on an extensive scale, 100 tons a day being recovered. The present plant recovers 160 tons a day and

[1] Wentworth Manning, *Some History of Van Zandt County*, Wills Point, Texas, 1919, p. 146.

the plant at Palestine salt dome 120 tons. The maximum production at Steen Saline during the war was probably 120 tons a day and the larger figure (1,200 tons) given by Burleson[1] in 1874 may have been a typographical error.

Richardson erected a plant at the northeastern edge of the salt core near the railroad and converted it into steam evaporation about 1888. The first salt well at Grand Saline was drilled for him by Marsden at about this time. The plant was enlarged about 1900 to a capacity of 750 barrels weighing 280 lbs. each and was operated from 1905 until 1919 by T. S. McGrain as the Grand Saline Salt Company. After two fires the property was sold to the Morton Salt Company and operations ceased.

Major Parsons erected the first plant for steam operation at Grand Saline on the southwest side of the town about 1886. The Lone Star Salt Company, Henry Blount, Southern Salt Company, and Fiedler Salt Company properties all located near together, were absorbed by B. W. Carrington and Company between 1902 and 1906 and later transferred to the Morton Salt Company. The capacity of the Morton plant has grown from 500 to 2,000 barrels a day.

Data concerning salt production has been furnished by Mr. McGrain of Grand Saline and by Mr. B. W. Carrington of Dallas. The total quantity of salt produced from the dome is estimated at 1 million tons or 28 million cubic feet or sufficient salt to lower the surface of the ground 4 feet over an area of ½ square mile. Actual removal of salt has been confined to the northern end of the salt core and the cap rock over the salt minimizes the amount of subsidence at the surface.

More salt has been removed from Grand Saline than from Palestine dome. Comparative production figures for the two domes from the beginning of commercial mining through 1923 where salt is secured by wells as contrasted with the two where salt is actually mined are as follows: Grand Saline, 1,000,000 tons, Palestine 500,000 tons,[2] Avery's Island, Louisiana, 2,578,399 tons, Weeks Island, Louisiana, 1,500,000 tons.

TOPOGRAPHY

Grand Saline is an excellent example of the type of salt dome with a central depression over the salt surrounded by a single ring of hills. If there is concentric drainage it is beyond the limits of the area mapped in Figure 3. The depression consists of a barren prairie with pools of water and a salt marsh drained by Saline Creek, which flows eastward to Sabine River. The creek formerly flowed through a channel north of its present course. Another example of a "wind gap" similar to this abandoned channel is to be observed at Palestine

[1] *Texas Geol. and Agr. Survey First Ann. Rept.*, Houston, 1874, p. 223.

[2] Mineral Statistics of the *U. S. Geol. Surv.*, give the total production for Texas to the close of 1923 as above 12,000,000 barrels or 1,750,000 tons.

salt dome. Fresh and brackish water springs surround Grand Saline as well as all other salt dome salines in eastern Texas.

Solution and removal of salt has not appreciably lowered the surface of the saline although very slow subsidence undoubtedly proceeds continuously. Several salt wells have caved, producing small craters.

The subdued topography is characteristic of the lower part of the Wilcox group. The hills west and north of the saline show outcrops in fresh cuts but the hills on the south and southeast sides are covered with sand which prevents the formation of fresh exposures.

GEOLOGY

Surface geology.—Grand Saline is nearer the outcrop of the Cretaceous formations than any other salt dome in Texas. Around it only the Lower Wilcox (Indio) is exposed. The salt core is overlain by Wilcox and by material which has washed in as the salt has been dissolved. It is 12 miles from Grand Saline to the base of the Wilcox near Wills Point and this group is 500 feet thick in the Lindsey well on the west flank of the uplift. The Wilcox consists typically of sandy shales and sandstones with thin ironstone concretionary beds and lignite beds. Plant impressions were noticed in the shales on the west side of the dome near the reservoir for the salt works.

Underground geology.—A number of shallow salt wells and three tests for oil have been drilled on the top and sides of the salt core. The logs of the wells are given in Bulletin 736 of the United States Geological Survey. The first test for oil, drilled by A. Wilderspin in 1902 to a depth of 875 feet, was located southwest of the dome and is shown near the edge of the map, Figure 4. The Hallville Oil and Gas Company Lindsey No. 1, on the west side of the dome is within the area underlain by the salt core and reached salt at 306 feet. Their Lindsey No. 2 was located $\frac{1}{4}$ mile west and did not reach the salt to a depth of 3,842 feet. The correlation of formations in this well has been the subject of great discussion because accurate correlations from rotary well cuttings without cores cannot be made. The base of the Wilcox is 645 (?) feet, the Pecan Gap chalk member of the Taylor marl was found from 2,664 to 2,740 feet and the Wolfe City sand member of the same formation from 2,740 to 2,960 feet. Dr.

L. W. Stephenson, of the United States Geological Survey, from a megascopic study, and Miss A. C. Ellisor from a microscopic study of cuttings agree that this well, with a total depth of 3,842 feet never reached the Austin chalk or a fauna of Austin age, but Miss Kniker, has found an Austin microfauna. The log of the Jewell and North Texas Oil Company's Davis No. 1, 4½ miles southeast of Grand Saline, on the J. J. Moore Survey, drilled to 4,093 feet shows limey material from 3,852 to 3,998 feet but this has not been identified.

The cross-section of the dome, Figure 4, has been drawn to scale

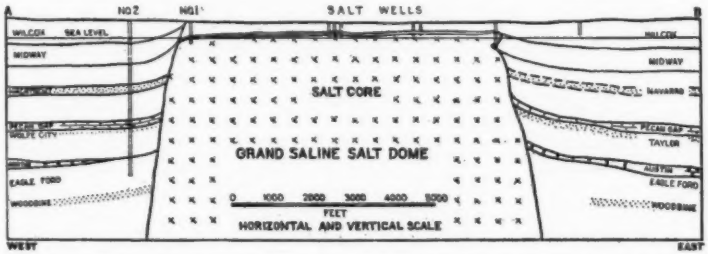

FIG. 4.—Cross-section of Grand Saline salt dome from west to northeast along the line *A–B* of Fig. 3 showing the location of the salt wells of Lindsey Nos. 1 and 2, and the small amount of uplift of strata adjoining the core of salt which is about 1½ miles in diameter. Erosion has truncated the top of the salt core, but has not revealed what has become of the sedimentary rocks from the space now occupied by the salt.

after a study of logs of wells in Van Zandt County. A normal columnar section of the Eocene and Upper Cretaceous is believed to be as follows:

	Feet
Wilcox group	650
Midway and Navarro formations	1,950
Taylor, including Pecan Gap chalk	800
Austin, Eagle Ford and Woodbine	1,000
	4,400

The salt wells are difficult to locate and describe because of occasional changes in the numbering scheme, but they are shown on the map of the dome. One group of four wells drilled by the Grand Saline Salt Company, but no longer used, is located ¼ mile east of the railroad station and south of the track. The next well farther

east (east of the town) is the Richardson well drilled by Marsden. The other wells shown on the eastern edge of the map did not reach salt. The original Lone Star Salt Company well is located near one of the buildings of the Morton plant a short distance west of the railroad station and north of the track.[1] The other Morton wells are located south of the track and west of the railroad station and as numbered by the superintendent, Mr. R. A. Egbert, may be described with reference to an imaginary square as follows: No. 1, NE. corner; No. 2 SE. corner; No. 3 SW. corner; No. 4 NW. corner; No. 5 center; No. 6, a short distance east of No. 4. Wells No. 2, 3, 5, and 6 are in use in February, 1924. The logs of the wells drilled in 1918 (Nos. 3 and 4) and in 1923 (Nos. 5 and 6) are given below.

TABLE III

No. 3		No. 4		No. 5		No. 6	
Feet		Feet		Feet		Feet	
0–5	Clay	0–8	Clay	0–2	Sand	0–3	Sand
30	Packed sand	20	Packed sand	12	Clay	15	Clay
80	Quick sand	90	Quick sand	100	Sand	100	Sand
125	Blue mud	210	Blue mud	120	Shale	125	Shale
148	Soapstone	212	Pyrite	145	Soapstone	143	Sandy shale
187	Chalk	238	Lime	155	Gumbo	156	Gumbo
195	Soapstone	400	Salt	164	Soft lime	170	Sandy shale
207	Hard sand			169	Lime and pyrite	172	Pyrite
223	Blue sand			185	Chalk	180	Chalk
225	Pyrite			196	Gravel	203	Black lime
235	Hard blue sand			197½	Cavity	210	Gravel
240	White lime			204	Quicksand	226½	Hard lime
402	Salt			210	Black lime	228	Cavity
				225	Chalk	245	Shale
				226	Cavity	403	Salt
				240	Shale		
				404	Salt		

The depth of the top of the salt in feet in various wells is as follows: Morton No. 1, 235; No. 2, 235; No. 3, 240; No. 4, 238; No. 5, 240; No. 6, 245; Grand Saline Salt Co. No. 1, 245; No. 2, 235; Richardson-Marsden well, 212. Information regarding the two other Grand Saline Salt Company wells is lacking. Lindsey No. 1 found salt at 306 feet. It appears that the salt has been dissolved over the core to a uniform depth and that solution of the salt and subsidence of the roof progressed slowly with the normal erosion at the surface and gradual lowering of the ground water table.

One more well, not numbered, was drilled to 236 feet in 1918 without finding salt and was abandoned.

Limestone and gypsum cap rock overlies the salt and in it casing of the salt wells is set. The new wells report cavities on top of the salt which may be due to solution since the first wells are drilled, but

[1] The log is given by William Kennedy, *Geol. Surv. of Texas Third Ann. Report*, 1892, p. 76, is 359 feet deep. It is reproduced on p. 220, *U. S. Geol. Surv. Bull. 736*.

the wells do not seem to have underground connection. The shale below the cavities in two wells may have been washed in from abandoned wells. The thickness of the cap rock varies from 16 to 45 feet. Oil is reported in two wells probably in the cap rock. Water sand is found below the cap rock in some wells and this water furnishes a permanent supply to be pumped from the bottom of the wells drilled 100 to 200 feet into the salt. In other wells and at the Palestine dome water must be pumped into the wells. A thick cap rock is necessary for successful salt recovery by wells because otherwise, as at Lindsey No. 1, the shale caves too badly.

Structure.—Dip arrows and degree readings in Figure 3 show the quaquaversal folding with a rapid gradation from 20° dips on the inner edge of the bed rock and the outer edge of the wash deposits over the salt core to 1° dips ½ mile away. It is important to note that the salt was formerly in contact with the present inner edge of bed rock and that the original top of the salt core was probably higher than the present surface of the saline prairie (Fig. 3). A plunge of over 3,800 feet in ¼ mile between Lindsey Nos. 1 and 2 in the outer edge of the salt core shows that the core must be a cylindrical plug rising from unknown depths. The original top of the salt plug must have been rounded like that of Jefferson Island, Louisiana.

Interior salt domes are very much smaller and sharper folds than ordinary structural domes in sedimentary formations. The diameter of the Grand Saline salt core is at least 1 mile and probably 1½ miles, and that of the surrounding uplift ½ mile. The Lindsey No. 2 log proves the insignificance of the uplift within ¼ mile of the salt core. The total area affected at the present land surface is 2½ miles in diameter and the amount of uplift of the exposed Wilcox beds less than 500 feet.

STEEN SALT DOME

LOCATION AND HISTORY

The Steen salt dome is in northern Smith County (Fig. 5), 5½ miles east of Lindale, 14 miles north of Tyler, and 2½ miles south of Sabine River. With reference to the Spanish grants it is in the northeast corner of the M. de los Angeles Carmona league. This dome is 24 miles southeast of Grand Saline and 27 miles northeast of Brooks salt dome. It is the northernmost of the five which are roughly

aligned. It is 26 miles southeast of Grand Saline and the same distance north of Brooks Saline.

A man named Stein or Steen appears to have acquired the saline about 1866 after the Cherokee Indians were moved to Indian Territory and his name, spelled Steen because of the way in which it was pronounced, has become attached to it. The patentee of a nearby Survey was John Steen and the early reports used this spelling. Little is known of the exploitation of the saline except that 3,000 people were engaged in making salt on it during the Civil War, and that the output is reported to have been 12,000 (?) sacks (1,200) tons[1] daily with 20 furnaces making a bushel of salt from every 190 gallons of water whereas at Brooks Saline only 100 sacks were made with 7 furnaces making a bushel from 300 gallons of water. In Louisiana during the war 100 bushels of salt a day were made at Drake's Saline, 1,000 bushels at Rayburn's Saline, and 350 bushels at Price's Saline.

Wm. C. Scott owned the saline for many years and quarried the calcareous limestone on its west side in 1868–70 burning lime in kilns at the quarry and using it in mortar for houses in Tyler. Silver was sought in the same rock, probably in galena, but the silver was proved by J. H. Herndon to be a myth. No galena has been observed in this rock by the writer.

Two wells were drilled for salt on the Scott estate about 1902 by Lestergett and their depths are reported to have been between 400 and 600 feet. Little is known regarding them and the belief that they reached salt at a depth of about 300 feet and below a hard cap rock cannot be verified. The Lindale Oil Company drilled a well on the Winters farm in 1920 as described below. W. F. Weeks *et al.* drilled a well on the Pierce farm in 1924, and found limestone cap rock from 75 to 207 feet, the total depth in August, 1925. It seems desirable to test these domes by a radial row of wells starting near the salt rather than to scatter locations around the dome and thereby merely outline the salt body for the benefit of the next prospector.

TOPOGRAPHY

Steen dome consists of a central saline marsh surrounded by a ring of low hills which are in turn surrounded by high hills. Trees cover the hills west of the saline and hide the topography. Dense underbrush and trees have encroached on the saline and very little bare ground is left. The swamp is about 6,000 feet long and 2,000 feet wide at the widest point. The saline during the Civil War covered 10 acres. The elevation of the lake is about 350 feet.

Saline Creek, flowing from south to north and emptying into the Sabine River, forms the swamp. Numerous springs empty into

[1] This is evidently a typographical error for 1,200 sacks.

the swamp, but they are not as noticeable as around other domes because the swamp occupies almost the entire depression. Undoubt-

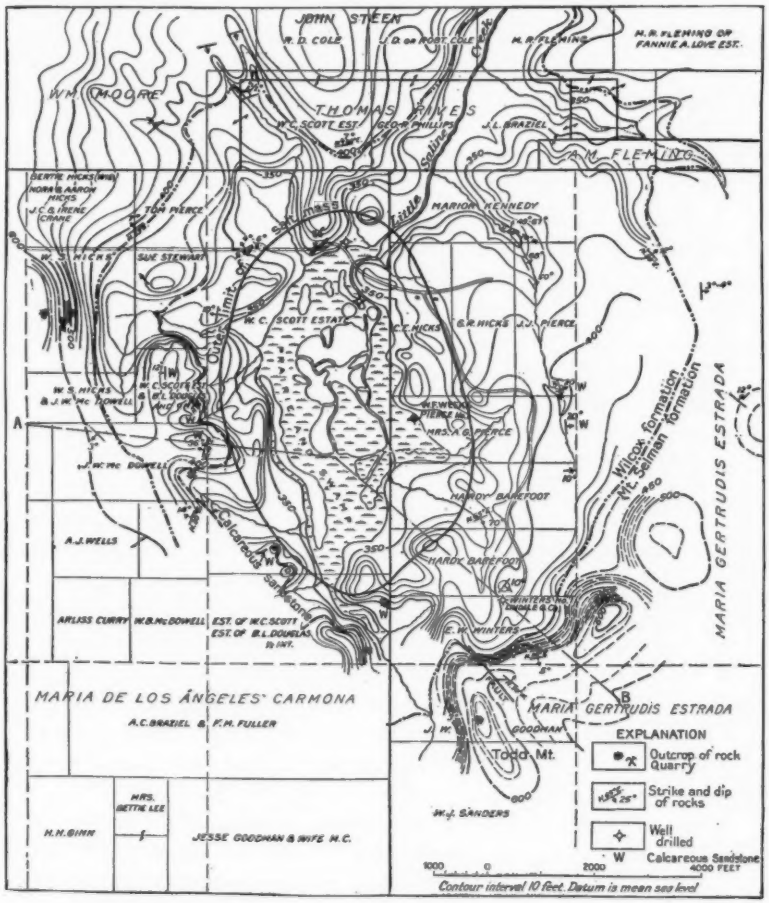

FIG. 5.—Topographic map of Steen salt dome reproduced with minor additions from *Bulletin 736*. This is another example of a central saline surrounded by hills. Circular drainage is beginning to develop outside the inner rim of hills.

edly the springs represent artesian water from sands of Wilcox age brought up along the outcrop and along faults and joints at the edge

of the salt core. A sulphur spring occurs in the northeast quadrant of the dome.

The topography is shown in Figure 5. The inner rim of hills rises 60 feet above the saline, the outer rim 150 to 250 feet. Radical drainage into the saline has formed the inner rim of hills from topographic benches of an earlier erosion cycle. Circular drainage is developing east of the saline and two small valleys are being cut behind the lower hills on the west side.

GEOLOGY

Surface geology.—Steen and Brooks salines lie in the area of the dissected Mount Selman formation which produces a pronounced wold and striking hills capped by very hard and resistant red ferruginous sandstone and iron ore. The outer rim of hills surrounding Steen Saline is composed of these sandstones dipping gently away from the dome. The most interesting observed outcrop of the Mount Selman formation is on the ridge south of the Winters well where a fault forms a "stone fence."

Soft red sandstone classified as Carrizo underlies the Mount Selman in Todd Mountain. Mount Selman iron ores, similar to those on Todd Mountain, shown at the southeast corner of Figure 5, were formerly mined at Rusk, in Cherokee County.

Lower Wilcox (Indio formation) sandy shales and sandstones, usually identified by the presence of lignite or of shales of lavender color, bearing plant impressions, underlie the Carrizo sandstone. The low hills and terraces surrounding the saline are underlain by beds of Wilcox age and exposures may be found in gullies. There is a marked discordance of dip between these sandy shales and the ironstones of the Mount Selman which may be observed on the west and southeast sides of the dome.

Calcareous sandstones and calcareous concretions crop out on five hills west of the center of the saline where they have been quarried. Another exposure is in a small creek which is developing a circular drainage pattern east of the center of the saline. Similar rocks are exposed at the south end of the lake. In Bulletin 736 of the United States Geological Survey the exposures on the west side were described as possibly of Midway age, but the later discovery of obscure plant fragments at the quarry indicates Wilcox age. The

sandstone is lithologically the same as that in West Point Mountain at Butler dome containing Wilcox plants. At the quarry, which was worked in 1868, a massive bed of gray calcareous sandstone 12 to 15 feet thick forms a miniature hogback with a strike N. 25° E. and dip 40° W. A second ridge of similar rock is found 500 feet west of the quarry and another outcrop occurs on the hill north of the quarry. The other hills are covered with ironstone concretions and remnants of the Mount Selman beds. The lime cementation is probably of very local occurrence and represents a secondary concentration corresponding to the iron in the ferruginous sandstone.

On the east side of the dome an exposure described in *Bulletin 736* on the Mrs. Pierce farm is now concealed but another exposure of calcareous gray sandstone was found southeast of the farmhouse. The dip is N. 70° E.< 20°. This bed is one foot thick, is highly jointed, and is so locally impregnated with lime that it does not crop out in the ploughed field up the dip. The presence of lignite in the water well at the farmhouse in lower beds as well as in water wells at houses near the main highway on the C. E. Hicks farm indicates that the calcareous rock is of Wilcox age.

No exposures of older rocks have been found- but local inhabitants report that many years ago fossiliferous shale was exposed in the first large branch north of the "limestone" quarry. The available stratigraphic section does not tend to verify this report.

The thickness of the Wilcox section below the "limestone" on the east side of the saline is over 100 feet and possibly 200 feet. The interval from this bed to the lowest ferruginous sandstone, near the Winters well is unknown. Between this later outcrop, which may be the base of the Carrizo sand, and the top of the hills 300 feet of Carrizo sandstone (?) is exposed.

Underground geology.—The only available information regarding the subsurface geology is from an analysis of the Winters log. This well starts in the Wilcox and must have passed through several hundred feet of this formation. The sand from 412 to 488 feet may be the base of the Wilcox. Gumbo, shale, and rock with only one thin sand from 488 to 2,495 feet must represent the Midway and the upper part of the Upper Cretaceous. Alternating sand and shale from 2,495 to 2,525 feet and alternating limestone and gumbo from

2,525 to 2,551 feet may represent the Pecan Gap chalk member of the Taylor marl. Shale and sand from 2,551 to the bottom of the hole at 2,630 feet may represent the Wolfe City member of the Taylor marl or the Pecan Gap chalk (Fig. 6).

The normal section may be as follows:

	Feet
Wilcox group	1,100
Midway and Navarro formations	1,900
Taylor including Pecan Gap chalk	1,000
	4,000

Structure.—Quaquaversal folding with dips of 30° to 70° in the Wilcox surround the saline. Intrusion of the salt core has pressed

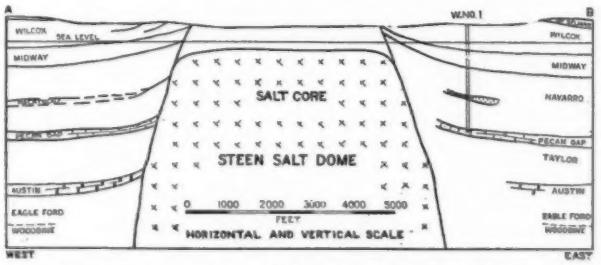

FIG. 6.—Cross-section of Steen salt dome from west to southeast along the line *A–B* of Fig. 5. The salt core is probably cylindrical in form because the area of uplift is small and the Winters well (W. No. 1) showed only slight uplift.

back the surrounding beds, but the effect of the intrusion diminishes rapidly away from the dome. Dips of 2° to 10° in the Mount Selman formation capping the outer rim of hills extend so near the steeply dipping Wilcox beds on the west and southeast sides of the dome that the relationship may be explained at a local unconformity. The Carrizo sandstone may be locally unconformable with the Indio formation of the ferruginous sandy beds on the west side of the dome near the "limestone" quarry. The amount of uplift of the strata nearest the salt core is about 500 feet.

A fault, marked by a "stone fence" of ferruginous red sandstone 5 feet in thickness, is found on the north flank of Todd Mountain and on the southeast side of the dome. The strike of the fault is N. 40° W., and the downthrow is 60 feet or more on the northeast side.

The upturned sandstone ridge is on the downthrown side. Slickensided surfaces of the sandstone indicate that the movement was vertical.

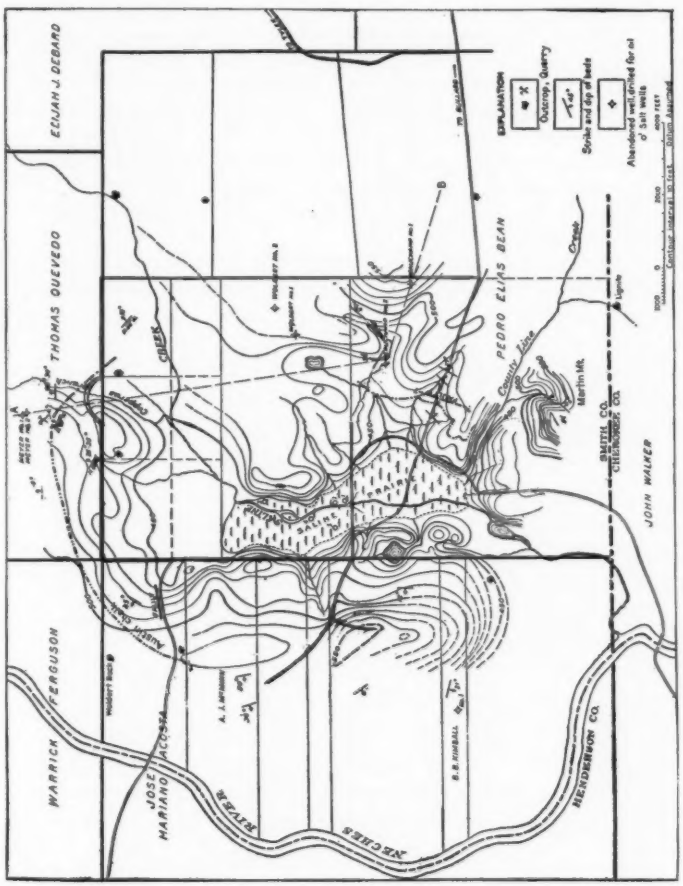

FIG. 7.—Topographic map of Brooks salt dome reproduced with changes from *Bulletin 736*. The Austin chalk is more widely exposed at the surface here than in any other salt dome. The central saline is an expansion of a creek valley, and is fed by salt water rising from artesian and ground waters some of which have come into contact with salt at a depth of 200–300 feet.

BROOKS SALT DOME

LOCATION AND HISTORY

Brooks salt dome (Fig. 7) is in the extreme southwestern corner of Smith County, 6 miles west of Bullard, 17 miles southwest of

Tyler, and 27 miles southwest of Steen dome. The saline prairie covers about 200 acres of the west half of the Pedro Elias Bean league.

Salt was evaporated here during the Civil War from salt water collected in shallow wells about 4 feet square and deep lined with wooden curbing. Seven furnaces were operated on the east side of the prairie and the production was 10 tons a day, 300 gallons of water making 1 bushel of salt.

Chalk was quarried from the north side of the dome and was used as flux in the iron ore smelters at Rusk, operated in 1885.

During 1903–4 five shallow wells were drilled for salt on the saline prairie and the deepest is reported to have encountered gypsum from 200 to 220 feet underlain by salt to 280 feet, the bottom of the hole. Distance from a railroad prevented exploitation of the salt.

Seven tests for oil were drilled by Dr. Albert Woldert and others of Tyler, Texas, during 1919–20 under the name Brooks Saline Oil and Development Company as described later.

TOPOGRAPHY

Brooks dome lies near the western edge of the wold formed by the outcrop of the Mount Selman ferruginous sandstones. The relief, like that at Steen dome, is as great as any in east Texas. The elevation of the saline prairie is probably about 430 feet and of the highest hills 550 feet.

The center of the dome is occupied by a barren prairie with a few low mounds covered by trees. The prairie is a lake in winter, a white, salt plain in summer. North and south of the prairie there is a swamp, that on the north being covered with marsh grass. Saline Creek rises northeast of the dome and flows through the prairie and into Neches River. Copperas Branch and County Line Creek and a number of short branches drain into the saline in radial manner.

High hills surround the dome on the west, northwest, southeast, and south sides. No circular drainage pattern has been observed outside these hills, but Neches River makes a large bend away from the dome and the hills on the west side slope gently to the river bottom.

GEOLOGY

Surface geology.—The formations represented at the surface are the Mount Selman (the type locality is 10 miles southeast), Wilcox (Carrizo sandstone and Indio formation), Navarro (?), Taylor, and Austin chalk. The shale on top of the ridge west of the prairie is probably Wilcox or Midway, not Eagle Ford or Taylor, as stated in

Bulletin 736. The Mount Selman formation caps the high hills on the north, east, and south, the Carrizo sandstone forms the sandy land on the east and north sides, the Indio has a narrow belt of outcrop and is exposed on the east side, and the Cretaceous formations surround the saline prairie except on the south where there are no exposures. Erosion on the west flank of the dome by Neches River has cut back the outcrop of the Eocene formations.

Chalk crops out on the east side of the dome in and near the road from Bullard to the saline. The exposure shows two beds, 5 and 10 feet thick, respectively, separated by 25 feet of green shale. Other streaks of chalk indicate that there is no massive bed. On the north side of the dome a small outcrop is found east of Copperas Branch. West of Copperas Branch and north of the settlement road there are two exposures, one at the quarry which is reached by a dim road through the trees, the other about 1,000 feet southwest of the quarry. The Meyer wells were drilled 1,500 feet north of the quarry and reached the chalk at 1,700 feet. At the quarry about 20 feet of chalk is exposed dipping N. 30° E. < 34°, underlain and overlain by greenish shale. Another exposure showing a number of thin beds of chalk occurs northwest of the saline and another was found by M. I. Goldman in the southwest quadrant of the dome in a ravine.

Dr. Stephenson determined the age of the chalk from large fossils as Austin. Among the common fossils are *Baculites*, *Ostrea plumosa*, *Gryphaea*, *Inoceramus*, *Hamites* (?), and fish. Microscopic examination of the chalk from the quarry and from the Bullard road shows a Taylor microfauna.

Clays of green or yellow color, originally blue, surround the dome and occur both above and below the chalk. Their age is in part Taylor, as determined from samples secured at the chalk outcrop on the Bullard road but they may be in part Navarro. Fragments of *Inoceramus* are abundant. Shales under the chalk at the quarry have an upper Austin fauna according to A. L. Selig.

The Midway formation has not been recognized at this dome unless the shales on the ridge west of the saline are of this age.

The Indio formation is exposed in the gullies on the east side of the dome and on the ridge on the west side. These clays contain claystone concretions with cone-in-cone and the only fossil found by Dr.

Stephenson was a *Serpula* tube filled with glauconite grains. There are microscopic fossils indeterminate in age. The absence of exposures near Woldert Nos. 1 and 2 was unfortunately construed to indicate a normal stratigraphic section instead of surface wash underlain by cap rock and by salt at 309 feet.

The Carrizo sandstone is probably exposed on the Bullard road east of the south end of the saline and also north of the limestone quarry and north of the limit of the map, Figure 7. In soft sandstone 500 feet east of Beauchamp No. 2, Dr. L. W. Stephenson found *Cardium, Corbula, Venericardia,* and gastropods which may be Carrizo.

TABLE IV

Name	Side Dome	Depth in Feet				Why Abandoned
		Cap Rock	Salt	Chalk	Total	
Wells of 1903	Center	200	220	.....	280	In salt
Woldert No. 1	East	195(?)	309	.....	429	In salt
Beauchamp No. 1	East	.....	.....	2,864	3,193	In "shale and gypsum"
Beauchamp No. 2	East	.....	1,343	765	2,161	In salt
Woldert No. 2	East	572	840	.....	850	In salt
Meyer No. 1	North	.....	.....	.....	528	Lost hole
Meyer No. 2	North	.....	2,744	1,684	2,769	In salt
Kimball No. 1	West	.....	.....	.....	1,864	Lack of funds

Mount Selman iron ores cap Martin Mountain on the Smith-Cherokee county line and here they are underlain by glauconite sand containing abundant casts of spired gastropods. Ferruginous sandstones also cap the hill east of Beauchamp No. 1 and the hills near Meyer Nos. 1 and 2 but they are probably Carrizo sandstone. There is an outcrop of lignite on the county line southeast of Martin Mountain, but the stratigraphic position is uncertain.

Conglomerates cemented with hematite and limonite are found at the north and southwest ends of the dome as well as in the form of boulders elsewhere. They are believed to be younger than the Mount Selman and to have been formed from the iron ores of that formation.

Underground geology.—Table IV shows the wells which have been drilled and their depth in the order drilled: The logs were printed in *Bulletin 736.*

Correlation of the logs is shown in Figure 8. Microscopic exam-

ination of the cuttings from two wells for microfaunas have been made by Dr. J. A. Udden, of Austin, Texas, and by Miss L. L. Lane, but the material was cuttings and not satisfactory. Alexander Deussen examined the cuttings when the wells were drilled and advises the writer that both Woldert No. 1 and Beauchamp No. 1 reached the Austin chalk.

Beauchamp No. 1 cuttings were described by Dr. Udden in a report to Dr. Woldert, of Tyler, but the writer does not have this interpretation on the age of the material. The well starts in red

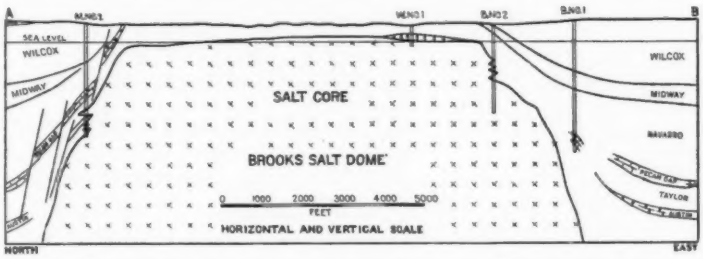

FIG. 8.—Cross-section of Brooks salt dome from north to east along the line *A–B* of Fig. 8 showing four of the wells drilled for oil (Meyer No. 2, Woldert No. 1, Beauchamp Nos. 1 and 2). Three of these tests found salt; two penetrated alternating beds of shale and salt. Pronounced squeezing (diapirism) of the formations has taken place around this dome, especially on the north side, so that the Austin chalk is brought to the surface and overlying formations are not exposed in nomal sequence.

sand, and lignite of the Wilcox was found at 98 feet. Lignite is reported to a depth of 1,460 feet, sand to 1,250 feet, and silty clay with some sand to 1,500 feet. Limestone fragments were found at 1,285 feet, 1,460 feet, from 1,590 to 1,620 feet, 1,860 to 1,870 feet, 2,010 to 2,040 feet, 2,110 feet, 2,884 to 2,924 feet; chalk from 2,600 to 2,610 feet at 2,650 feet, from 2,740 to 2,770 feet. The first Foraminifera were noted at 1,745 feet and the next at 1,934 feet. They became abundant below 2,310 feet. *Inoceramus* fragments were found between 1,800 and 2,500 feet. Bentonite is reported from 2,010 to 2,060 feet. Sandy clay from 2,392 to 2,445 feet is underlain by clay containing *Ostrea congesta* (?). A fish tooth at 2,610 feet indicates Eagle Ford age. Alexander Deussen identified the Austin chalk in this well at 2,864 feet.

Meyer No. 2 is located 1,500 feet north of the limestone quarry and reached the Pecan Gap chalk at 1,684 feet. Cuttings were described by Miss L. L. Lane in a report to Alexander Deussen dated February 23, 1924 and the following notes are made from that report.

TABLE V

Depth in feet	Character of Material
374, 523, 1,010, 1,128, 1,193, 1,361	Clay with some sand
1,516	Sand and clay
1,552	Limey shale with Foraminifera
1,650–1,701	Clay with prisms of *Inoceramí* shells; a Taylor microfauna.
1,705	White chalky limestone, practically the same fauna.
1,539	Sandy clay, *Globigerina*.
1,722–1,739, 1,767	Clay and limestone, 12 species of Foraminifera of Taylor age
1,781–1,789	Clay, Taylor fauna, *Inoceramus*
1,995	Soft gray limestone, Taylor fauna
2,000–2,004	Sand and clay, prisms of *Inocerami*, Taylor fauna
2,012–2,136	Clay, same fauna
2,136–2,146	Gypsum
2,161	Core of rock salt
2,246	Clay and sand, same Taylor fauna
2,271–2,362	Clay, slight change in fauna
2,402–2,452	Sandy clay, typical Taylor association of forms reappears
2,453	Same, with impure coal.
2,536–2,551	Sand
2,605	Core of clay with glauconite grains, *Inoceramus*, 4 species of Foraminifera
2,706–2,716	Sandy clay, Taylor fauna

Miss Lane writes of the Meyer well: "It is impossible to tell where the Taylor fauna should disappear because of the evident mixture of material. The fauna changes slightly at 2,271 feet, but the typical association of forms reappears. Whether this reappearance occurred or whether the Foraminifera came down the hole cannot be determined." The sand at 2,386 feet in the Meyer well was called "Woodbine" prior to this microscopic study but it may be a stray sand. Miss Lane also examined a core of chalk from the Sinclair Oil and Gas Company Brooks well, on the B. S. Watts survey, $7\frac{1}{2}$ miles northeast of Tyler, or 22 miles north of Brooks dome. This white chalky limestone was found from 3,195 to 3,310 feet and the

exact depth of the core is not known. Miss Lane states: "The fauna does not correspond to that of the Austin or of the Taylor. Probably it represents a transitional phase." Miss A. C. Ellisor also examined this chalk and states: "This chalk contains a larger number of Foraminifera than is usually found in the typical Austin chalk and I believe it to be the Pecan Gap." These determinations indicate that the chalk in the Meyer well is probably Pecan Gap.

A normal stratigraphic section in the vicinity of the dome is believed to be as follows:

	Feet
Mount Selman formation	0– 100
Wilcox group	1,200
Midway and Navarro formations	1,900
Taylor marl, including Pecan Gap chalk	1,000
	4,200

Structure.—The diameter of the area uplifted at Brooks dome does not exceed 3 miles although the diameter of the salt is over $1\frac{1}{2}$ miles at a depth of 500 feet and about $1\frac{3}{4}$ by 2 miles at a depth of 3,000 feet with the longer axis from north to south. The pitch of the edge of the salt core is not as steep as on the west side of Grand Saline. The amount of uplift of the Navarro-Taylor series which seems to surround the dome is about 3,500 feet and of the Austin, 4,300 feet. Squeezing (diapirism) has forced the older shales and the Austin chalk past the younger shales around the circumference of the salt core so that the Taylor is in contact with the Wilcox. Faulting may have aided this squeezing in the southeast quadrant, but the underthrusting of fragments of formations is not as notable as at Palestine dome.

KEECHI SALT DOME

LOCATION AND HISTORY

Keechi salt dome, named from Keechi Creek and not to be confused with the town of Keechi in Leon County, is situated $7\frac{1}{2}$ miles by road, 6 miles in an air-line northwest of Palestine, Anderson County, on the Montalba and Athens road. The center of the saline is on the W. A. Cook survey. This dome is 13 miles northeast of Butler dome, 6 miles northeast of Palestine dome, 30 miles southwest

of Brooks dome, 55 miles southwest of Steen dome, and 60 miles south of Grand Saline.[1]

This salt dome is not a conspicuous topographic feature because there is no central lake or barren prairie and no "race track" of barrens around the partly circular drainage. It was described by E. T. Dumble in the *Second Annual Report of the Texas Geological Survey*, in 1891, but it was not rediscovered until 1915 and then by W. I. Sims and L. C. Chapman. It was visited by O. B. Hopkins and by the writer in 1916 and described briefly by the former in Bulletin 661 of the United States Geological Survey. The topographic map of the dome (Fig. 9) was made by the writer in 1924 prior to the completion of the new concrete highway, but this is shown running in an almost straight line across the dome. Exposures are abundant at the side of the old road and all references are to that road.

Salt has never been evaporated here and the only evidence of salt, except for sparse vegetation and a small salt lick in the flat creek valley, is its discovery in the Producers Oil Company's well. The salt must be at a greater depth than in the other interior domes.

Five wells are drilled on the south side of the dome in 1916–17 by the Producers Oil Company (the Texas Company) on the Barrett and Greenwood land. The first had a showing of 8° Baumé gravity oil at a reported depth of 1,686 feet which might have made a well.

TOPOGRAPHY

Keechi dome is situated about 2 miles west of the Mount Selman escarpment. Dissected ferruginous red sandstones and weathered glauconite beds of the Mount Selman formation and, locally, hard beds in the Carrizo sandstone, produce a relief of 100 to 150 feet. The topographic map, based on mean sea level as datum, shows the intricate character of the topography. Salt Fork of Keechi Creek flows through the northern half of the central core of the dome in a broad valley and along its floor are a few semi-barren patches which are salty in summer. Keechi Creek, and its headward portion called Spring Creek or Wagoner Branch receives the drainage from the

[1] Evidence of an uplift which may prove to be a salt dome has been discovered by M. A. Davey along the Neches River about 5 miles east of Neches, Anderson County, and 15 miles east of Keechi dome.

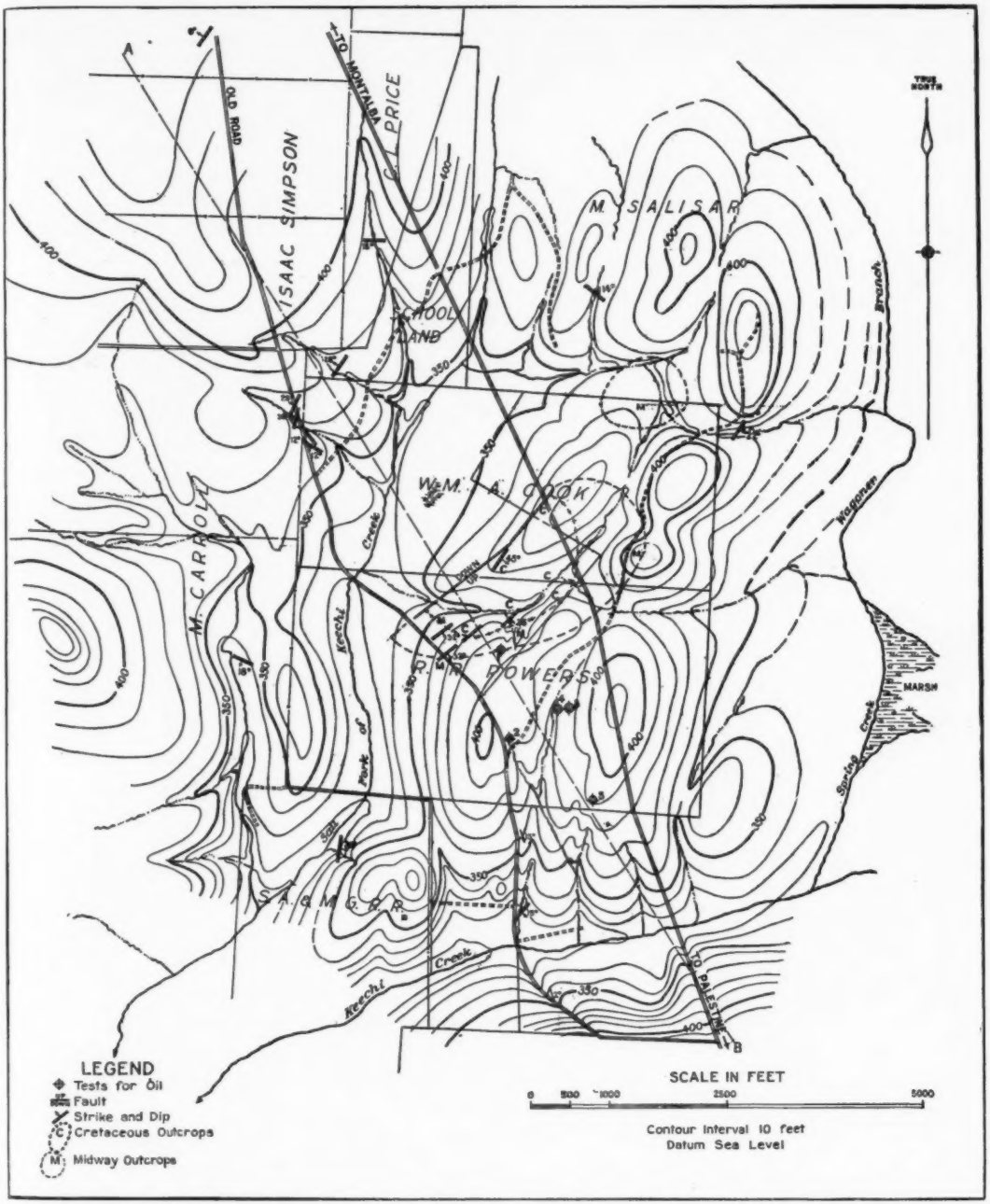

FIG. 9.—Topographic map of Keechi salt dome showing the fault through the center of the dome with Pecan Gap chalk on the south side thrust upward in contact with the Wilcox. Owing to the preservation of the original roof of the salt core, there is no conspicuous central saline. Circular drainage is enveloping the dome. The northernmost well, Barrett and Greenwood No. 1, had a showing of oil which led to the drilling of four additional tests.

northeastern part of the dome and flows in a semicircle around the western side of the dome. On the southwestern side it is joined by Salt Fork and farther west by drainage from the west side of the dome. The center of the structural dome occupies the area between Salt Fork and two tributaries which almost surround the rounded hill on which the conspicuous fault is located. This is the only Texas salt dome in which the original strata can be identified over the top of the dome.

Springs, which are characteristic of salt domes, are not conspicuous. There are springs along Salt Fork and along the valley of Keechi Creek, which cause boggy, grassy flats and a marsh on the southeast side of the dome. Mineralized springs were not noticed, but several dug wells have found salty water. A small marsh is situated on the broad, flat area south of Salt Fork and north of the fault. The hills north and west of Salt Fork do not show influence of steep dips. Those south and east rise more abruptly on the side toward the center of the dome and slope gently in the direction of the steeply dipping rocks beneath. The outer rim of hills south of the dome has a steep slope toward the dome.

GEOLOGY

Surface geology.—Keechi presents the unusual feature of a central fault of considerable magnitude which brings the Taylor chalk and clays on the south in contact with the Wilcox beds on the north. This fault was not noted in the earlier examination of the dome by Hopkins.[1]

North of the fault the outcrops for over a mile have been mapped as Wilcox because the shales at the fault look like Wilcox shales and because the occasional ironstone concretionary beds in the exposures along the highway are similar to those in the Wilcox. Lime nodules ¼ inch in diameter are very abundant in the outcrops along the road. Yellow Midway shale containing pebbles of calcareous mudstone filled with cone-in-cone structure are exposed in the eastern part of the Cook survey and also a few hundred feet north of the northeast quarter of that survey. Unquestioned Wilcox crops out farther away, overlain by the Carrizo sandstone.

[1] The fault is mentioned by W. G. Matteson, *Amer. Inst. Min. Engrs., Bull. 134*, 1919, p. 445.

South of the fault yellow, waxy shales containing thin lenses and fragments of yellow and white fossiliferous limestone containing *Ostrea* are tilted steeply to the southwest. The limestone is blue where fresh. A new chalky limestone exposure was made in excavating for the concrete highway. The age of the limestone and chalky limestone is probably Taylor. Alexander Deussen remembers collecting an *Exogyra ponderosa* of Taylor age in this general area several years ago. Microscopic study of the limestone and chalky beds by A. L. Selig show an abundant basal Taylor microfauna. He correlates the chalk with that at Brooks dome.

Shale beds are continuous from the Taylor southward across a small valley tributary to Salt Fork and are exposed in the side of the old highway on the north facing hill. In the ploughed field northwest of Producers Oil Company well No. 1 two lenticular beds of chalk each about 2 feet in thickness crop out south of the yellow limestone blocks, surrounded by the same yellow clays. White chalk was observed several years ago by Alexander Deussen and L. C. Chapman ½ mile northeast of this outcrop and the microfauna at that locality is either Midway or Navarro, probably Midway.

South of the chalk and also on its strike both northeast and southwest yellow Midway shales are found in what appear to be continuous, unbroken exposures. Faulting must be concealed in the weathered outcrops and the entire section is not exposed.

Dr. L. W. Stephenson identified fossils for O. B. Hopkins as belonging to the *Exogyra cancellata* subzone of the *Exogyra costata* zone which constitutes the lower part of the Navarro formation. These were collected from shales in the gullies 300 feet north of well No. 1, and also along the large east-west valley. He also identified fossils from the fields near these gullies and states that they came from the middle or upper part of the Navarro formation. The locality is evidently shale resting on the easternmost chalk. In the following list the first 6 forms are the Hopkins' collection, the next 14 forms the writer's collection from shale resting on the westermost chalk, identified by Dr. Stephenson in March, 1924. These chalk lentils and the overlying fossil bed are probably very near to the top of the Navarro according to the personal examination of Dr. Stephenson in December, 1924. The microfauna is Navarro, approximately the age of the Nacatoch of Louisiana according to A. L. Selig.

Nucula, cf. *N. eufaulensis*
Trigonia sp.
Plicatula n. sp.
Crassatellites sp.
Ringicula sp.
Baculites sp.
Cliona sp. (a sponge)
Unidentified corals
Leda sp.
Cucullaea sp.
Ostrea sp.
Trigonia sp.
Unicardium (?)
Crassatellites sp.
Anchura sp.
Unidentified gastropods
Nautilus sp.
Pachydiscus sp. (resembles a species from somewhere in Clark County, Arkansas)
Baculites sp.
Belemnitella americana (Morton)

Dr. Stephenson makes the following comments regarding the collection of March, 1924:

The fossils from the south side of the Keechi uplift are mostly casts in a poor state of preservation. With one exception I have been able to identify them only generically, but the one identifiable species, *Belemnitella americana* (Morton), has, I think, a definite significance in correlation, and indicates the upper Navarro age of the containing bed. This species is fairly common in places in the upper part of the Navarro formation, and in beds of the same age in other parts of the Atlantic and Gulf Coastal Plain. The species has not, to the best of my knowledge, been found in beds older than the Navarro. Although this collection is poorly preserved, the condition of preservation appears to me to be the same as that of fossils from a horizon at the top of the Navarro southeast of Greenville, Texas, and I am inclined to believe that it actually represents that horizon.

The collection was made from the easternmost chalk and the identifications by Dr. Stephenson, dated April 30, 1924 of forms not found in the earlier collections are as follows:

Nemodon sp.
Exogyra costata Say (?)
Cuspidaria sp.
Gastrochaena americana Gabb (?)
Unidentified pelecypods
Gyrodes (2 species)
Turritella sp.

Midway Foraminifera have been found by D. C. Barton in the head of the gully north of well No. 1 and in the gully at the side of the old road west of this well. The first locality yielded an upper middle Midway microfauna, the latter locality an upper Midway

microfauna overlain by the Wilcox sand. The shales excavated by the new concrete road in the south side of the dome and the shales north and east of these exposures are also Midway according to Dr. Stephenson and A. L. Selig.

Underground geology.—The Producers Oil Company wells on the Barrett and Greenwood land were a great disappointment to the land owners because great secrecy was maintained after the first well struck oil at 1,686 (?) feet and because no tests were made north of this well. An excellent showing of 8° Baumé gravity oil was found, but the log of the well records sand at 1,647 feet and fails to mention a showing either then or at 1,686 feet. Dr. J. A. Udden examined cuttings from well No. 4 and wrote Mr. A. G. Greenwood on August 25, and November 14, 1917 that it was drilling in the Eagle Ford or Woodbine at a depth of about 2,400 feet.

A tentative correlation of well logs has been made, but the identification of formations is a guess. Well No. 1 penetrated chalk from 545 to 560 feet. No. 2 reports chalk from 952 to 964 feet, and No. 3 chalk from 1,111 to 1,140 feet. These may be the same. This thin bed is near the base of sandy series of Navarro age which must include the Nacatoch sand. Several beds of chalk separated by shale underlie the Navarro and must be of Taylor age. The first chalk of Taylor age, the Pecan Gap, crops out along the fault, as stated above, and is probably the first chalk found in each well. The chalky series is 700 to 800 feet thick and can include the Austin only if 700 feet of Taylor section is missing. The age of the persistent sand series under the chalk is Taylor (Wolfe City sand?) if all the chalk is Taylor; otherwise it may be Blossom. The "lime, gypsum, and packed sand" 900 feet below the top of the Pecan Gap has more nearly the normal interval of 1,200 feet to the Austin, but Dr. Udden found fish teeth in this series which seem to indicate Eagle Ford age. Such an abnormal thinning of the section would indicate squeezing (diapirism) or faulting near the salt core (Fig. 10.)

Salt was found by well No. 1, as an apophysis of the main mass 660 feet thick underlain by sandy beds which may also be of Woodbine age. The well was drilled into salt again and stopped in it. It is unfortunate that these wells were not tested more carefully and drilled deeper.

Table VI is a tentative correlation of the Barrett and Greenwood wells:

Roeser Petroleum drilled two wells near Montalba and about 5 miles northwest of Keechi dome in 1922–24 on the Via and Brooks-Auld farms to depths of 4,331 and 4,165 feet, respectively, and in July, 1924 drilled a twin to the former to 4,411 feet. Miss Ellisor found a Taylor microfauna in cuttings from the Brooks-Auld well from a depth of 3,600 to 4,100 feet. From a microfaunal study of cores F. X. Bostick identified Pecan Gap chalk from Brooks-Auld well at 3,424 feet.

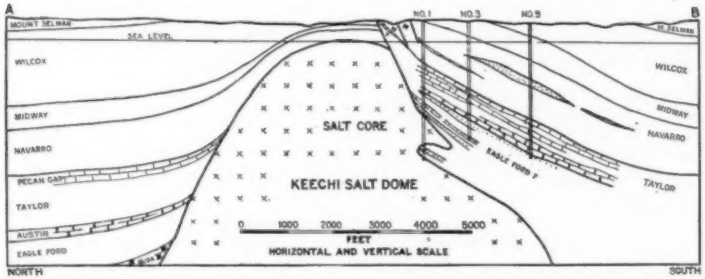

FIG. 10.—Cross-section of Keechi salt dome from north to south along the line *A–B* of Fig. 9 showing how the salt has elevated and faulted the south half of the dome. More faulting has taken place than is shown. This is the only interior salt dome in Texas where the original roof of the salt core is preserved in place.

In 1925 Roeser Petroleum drilled two more wells. Brooks-Auld No. 2, 250 feet east of No. 1, had Pecan Gap chalk at 3,399 feet with a Taylor microfauna underlain by a thick shale series with selenite crystals and several sandstones. The sandstones are of Taylor age and the lower part of the shale, Austin. Hard white chalk like that at Palestine salt dome was found from 4,620 to 4,820 feet, and is called Austin. Eagle Ford fossils were found by Miss Ellisor in 30 feet of black shale under the chalk. Dry sand from 4,850 feet to 4,895 feet was underlain by more black shale to 4,925 feet with an Eagle Ford fauna. The oil sand at 4,386 feet in the Via well was not found in this well. The other well, Daniels No. 1, 12 miles west northwest of Montalba on the Chas. Gilmore survey had Pecan Gap chalk at 2,827 feet and Taylor and Austin (?) shale from 3,250 feet to below 4,090

TABLE VI

	No. 1 El. 385	No. 2 390	No. 3 387	No. 4 380	No. 5 390
Sandy series, Wilcox (?)					0 – 221
Shale, Midway, Navarro		0– 469	0– 486	0– 426	221 –1,332(?)
Sandy shale, Navarro, Nacatoch in part (?)	0– 583	469–1,129	486–1,194	426–1,200	1,332(?)–1,886(?)
Shale, Navarro	583– 951	1,129–1,592	1,194–1,566	1,200–1,537	1,886(?)–2,091
Chalk with shale breaks, Pecan Gap at top	951–1,647	1,592–2,140	1,566–2,200	1,537–2,247	2,091 –2,888
Sandy shale; oil, gas, salt water, Wolfe City (?) or Blossom (?)	1,647–1,792 (oil 1,686?)	2,140–2,297 (gas 2,142?, water 2,257)	2,200–2,424	2,247–2,407 (gas 2,314, water 2,341)	2,888 –3,048
Lime and "gyp," Austin (?)	1,792–2,032		2,424–2,656	2,407–2,447	
Sand, sandy shale	2,032–2,162			(fish teeth)	
Salt	2,162–2,822				
Heavy oil sands	2,822–2,899				
Sandy shale	2,899–3,091				
Salt	3,091–3,170				

feet with Austin chalk from 4,090 to 4,300 feet. Brooks-Auld No. 2 found salt water, oil, and gas in the Woodbine sand from 5,206 to 11 feet and was abandoned at 5,231 feet. The Daniels well had salt water in the Woodbine sand from 4,963 to 5,010 feet, the total depth.

The section of Brooks-Auld No. 2 is interpreted as follows:

	Feet
Mount Selman and Wilcox	1,575
Midway, Navarro, and Taylor	2,380
Austin shale and chalk (part Taylor?)	865
Eagle Ford	

The interval between the top of the first (Pecan Gap) chalk and the Taylor water sands agrees so closely with the interval in the Barrett and Greenwood wells that the sands are believed to be the same. The Producers Oil Company wells on the Southern Pine Lumber Company and on Royall and Davey fee near Jarvis, in Anderson County, and the Atlantic Oil Producing Company's well at Ironton, Cherokee County, had a similar section. The first well appears to have reached the Pecan Gap chalk at 3,200 feet and to have stopped in the Taylor section at 4,346 feet. Several sands are reported in the Taylor. The Atlantic well had the Pecan Gap chalk at 3,765 feet. The Colliton Syndicate Clapp well 5 miles northwest of Ponta in Cherokee County is reported to have had the Pecan Gap chalk at 3,189 feet and a showing of oil in a sand in the Taylor at 3,567 feet and salt water at 4,242 feet. The showings of oil in this Taylor series in the Via, Barrett and Greenwood No. 1, and Colliton wells indicates a producing horizon above the Austin chalk which may prove commercially productive. The Woodbine sand may be found at a normal depth of about 5,300 feet, but this formation does not occur on the Sabine uplift and may not be found in the trough of the east Texas geosyncline. The Eagle Ford holds promise of commercially productive sands.

Several new wells will be drilled in 1926 by the Navarro Oil Company, the first being near Barrett and Greenwood No. 1.

Structure.—Keechi dome interrupts the normal southeast dip of 40 to 80 feet to the mile over an area over $3\frac{1}{2}$ miles in diameter with a salt core which may be 4,000 feet long from northeast to southwest

and 3,000 feet wide. The amount of uplift of the oldest strata (Taylor) exposed at the surface is 3,500 feet. The steepest exposed dips are 45° and those at the margins of the map, Figure 9, 1½ miles from the center of the dome, are 2°.

Faulting is the conspicuous feature of this dome. A fault with a throw of about 2,000 feet cuts across the dome along the major axis as stated above in a N. 50° E. direction. The line of faulting is sharply marked on the surface for about 1,000 feet by an abrupt change in the color of the soil in ploughed fields as well as by a steeply tilted bed of yellow limestone on the south side in contact with Wilcox clay and by numerous veins of calcite some of which show casts of slickensides.

Other faults, both radial and tangential, separate the chalk lentils from the Midway shales on the south side of the dome a short distance northwest of well No. 1 because the chalk appears in a very limited outcrop. Calcite marks one possible fault line near the chalk. Faulting, or rather underthrusting, may bring up the Midway cone-in-cone material on the northeast side of the dome, because part of the normal sedimentary section is absent around these inliers.

Preservation of the original roof over most of the salt core with no evidence of subsidence is characteristic of the more deeply buried domes.

PALESTINE SALT DOME

LOCATION AND HISTORY

Palestine salt dome (Figs. 11 and 12), named and described by E. T. Dumble and later by O. B. Hopkins, is in Anderson County on the Elias G. Myers survey, 6 miles south of west of Palestine and 4½ miles east of Trinity River. It is on the line between Butler, Keechi, and Steen domes and is about 6 miles distant from each of the first two. Palestine dome is the largest of the Texas interior salt domes and uplifts the strata over an area over 4 miles in diameter.

This dome was formerly called the "Salt Works" because the Palestine Salt and Coal Company has made salt here since 1904. Salt is obtained from shallow wells as described later. It was evaporated here in small quantities in kettles during the Civil War. No deep wells have been drilled in this vicinity. Mr. A. L. Bowers drilled a well near Tucker, 3½ miles south of the dome, to 2,330 feet.

A lignite mine was opened 1¼ miles northeast of the dome in 1923 and three seams each 7½ feet thick are mined. The lignite is used at the salt works.

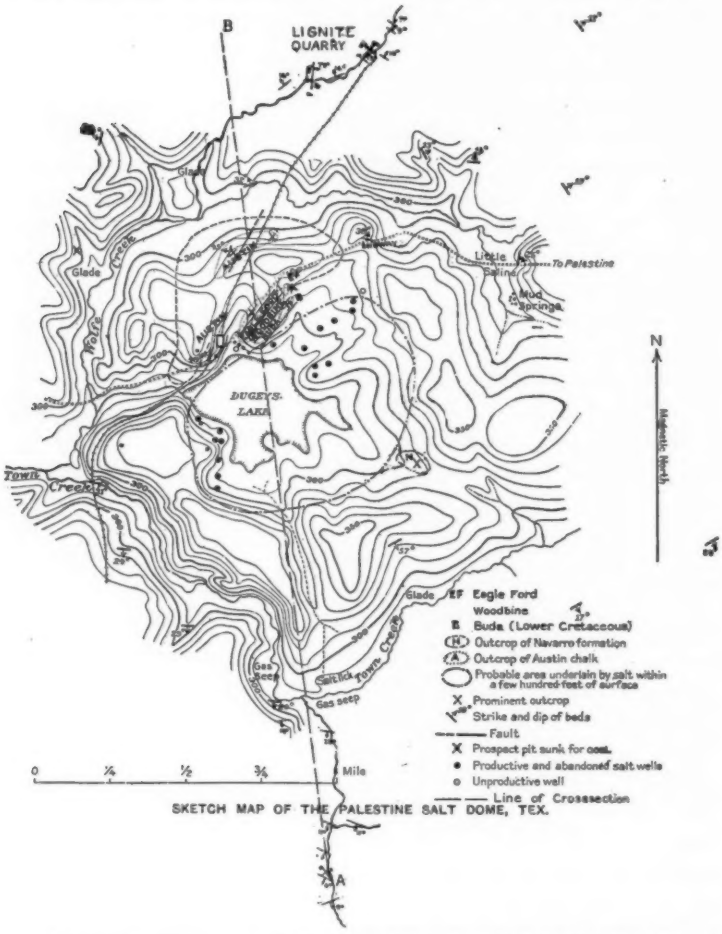

FIG. 11.—Topographic map of Palestine salt dome from *Bulletin 661* with additions. The central saline (an artificial lake) is surrounded by two concentric circles of hills separated by a circular drainage system. Salt is mined by means of wells and is evaporated in the plant north of the lake. The older Cretaceous formations crop out north and northeast of the lake.

TOPOGRAPHY

Palestine dome is the best example in Texas of a central lake, Dugeys lake, surrounded by hills which are in turn surrounded by circular drainage. One hill on the east side separates the head of Wolfe Creek on the north from a branch of Town Creek on the south. In place of the almost circular barren saline "race track" around Butler dome and Price's dome in Louisiana, there are swampy prairies and one real saline. Dugeys lake when visited by Dumble

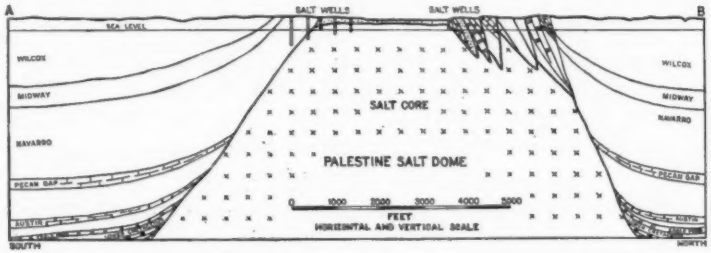

FIG. 12.—Cross-section of Palestine salt dome from south to north along the line *A–B* of Fig. 11 showing a large area of uplift owing to the conical shape of the salt core. Fragments of Lower Cretaceous limestone, Woodbine(?) sand, Eagle Ford limestone, and Austin chalk have been torn off by the intrusion of the salt and thrust upward about 1 mile in the form of blocks, the truncated edges of which are exposed on the north and northeast sides of the dome. This underthrusting illustrates the enormous force accompanying the intrusion of a core of salt through a vertical distance of 1¼ miles or more.

in 1891 was a small pool of water in winter only and was surrounded by a broad saline. The present lake, which is approximately ½ mile in diameter with a maximum depth of 4 feet, was formed by the construction of the railroad embankment which acts as a dam. Removal of salt from the top of the dome may have caused very slight subsidence.

Hopkins' topographic map (Fig. 11) shows that the elevation of Town Creek is about 275 feet, that of Dugeys lake 280 feet, the inner hills 340 to 350 feet, the outer hills over 350 feet. Trinity River at the mouth of Town Creek is about 200 feet above sea level. The dome is near the northwestern edge of the cuesta or wold—the Nacogdoches wold[1]—formed by the iron ore beds of the Mount

[1] Alexander Deussen, *U. S. Geol. Surv. Water Supply Paper 335*, p. 16.

Selman and this cuesta has an elevation of 500 feet within a few miles of the dome.

Little Saline, on the road to Palestine northeast of the salt works, is the most barren area around the course of the circular drainage. The steep northeast dip in the top of the salt core, as proved by wells east of the works, indicates that Little Saline and the other springs are fed by saline water which rises from salt water-bearing sands along their outcrops or else along faults or joints and not from the salt core. Many other springs are found along Wolfe and Town creeks.

Gas seepages are very numerous along Town Creek. The gas rises with the artesian flow of water and does not indicate the presence of gas in commercial quantities. An analysis of the gas given by Hopkins shows a high content of nitrogen and low content of carbon dioxide.

Mud volcanoes and mud springs in the process of building small domes may be observed on the southeast side of Little Saline. Gas bubbles rise with the water through the soft blue mud. A pole may be pushed down over 6 feet in these craters which vary from 1 to 3 feet in diameter.

GEOLOGY

Surface geology.—A greater number of formations crop out at this dome than at any other in the United States. These are: the Mount Selman, Carrizo, Indio, Midway, Navarro, Taylor, Austin, Eagle Ford, Woodbine (?), and Washita (Lower Cretaceous). This remarkable section is accounted for by the upthrust of the salt mass breaking off blocks of the older formations and thrusting them past one another in advance of and at the side of the salt core (Fig. 12). Fragments, only, of the formations below the Wilcox group are exposed and these fragments dip very steeply. The fault planes and the softer beds are not exposed and the details of the underthrusts can only be inferred. These blocks may correspond to the "breccia" of older rocks described on the top of several Roumanian salt domes. The Cretaceous is normally exposed 40 miles west of this dome.

Limestone below the Woodbine was not mentioned by Hopkins and was shown the writer by Mr. M. A. Davey, of Palestine. It is a hard, dense white rock which can be fractured with difficulty and is

very different from the brittle Austin chalk. It contains casts of fossils, a small, smooth *Exogyra* sp. and an impression of an ammonite which appears to be a Lower Cretaceous form. According to Dr. L. W. Stephenson and Miss L. L. Lane (personal communication) it is probably Buda, the highest formation in the Washita group of the Lower Cretaceous. About 25 feet of limestone is exposed on the south side of the hill south of the Woodbine sand. Evidently it was formerly in contact with the salt, because nearby salt wells find salt at about 150 feet overlain by secondary deposits.

Woodbine sand is not found in any other inlier in east Texas or north Louisiana. The outcrop forms a ridge on the south side of the hill east of the salt works and is made up of 20 feet of pure, hard, gray to yellow friable sandstone with low iron content. It would make an excellent oil sand. The strike is N., 30° E., and dip 46° NW. Poorly preserved interior casts of pelecypods can be found by breaking open the sandstone. These have been identified by Dr. L. W. Stephenson as *Ostrea* sp. and *Modiolus* sp. ("poorly preserved, but closely resembles a species found in the Woodbine near Arlington, Tarrant Co."). Dr. Stephenson remarks: "So far as the evidence goes it tends to confirm the Woodbine age of the containing sandstone, but I do not regard this as very strong evidence. *Modiolus* has a long range and species of different ages have a general similarity in appearance." It is possible that this is one of the sandstones in the Eagle Ford found by Roeser Petroleum at Montalba.

Eagle Ford limestone overlies the Woodbine (?) sand in the ridge southeast of the salt works and has an exposed thickness of about 5 feet. The limestone is separated from the Woodbine sand by a few feet of rocks which are not exposed, but it is overlain directly by the Austin (Annona). Fossils are abundant and may be collected under one of the small houses nearest the salt works. Dr. L. W. Stephenson identified those collected by Hopkins as of Eagle Ford age.

Another locality was found on the main highway $\frac{1}{3}$ mile east of the salt works. Eagle Ford microfossils were identified by A. L. Selig in shale from a dug well between the Salt Works and the northern block of Austin chalk, and west of the railroad spur to the lignite mine.

Austin chalk forms the south side of the hill west of the plant and

crops out on and near the road to Palestine north and northeast of the Eagle Ford. It also occurs on a hill ½ mile north of the works and is well exposed in cuts in the railroad to the lignite mine. The duplication of outcrops is due to faulting and a thickness of over 25 feet of any bed is difficult to prove. The chalk is massive, brittle, fractures irregularly, and is gray where freshly quarried but becomes white on exposure. The strike is in general N. 15°–30° E. The dip 40°–50° NW. The availability of the chalk has led to its wide distribution for road metal and abandoned mud holes provide interesting "outcrops."

Identification of the Austin (Annona) chalk by means of several species of *Inoceramus* was made by Dr. Stephenson. Two very large specimens presented to the Southern Methodist University at Dallas were identified by Professor E. W. Shuler as resembling *Inoceramus vanuxemi* Meek and Hayden. Dr. Stephenson identified *Inoceramus* sp., *Ostrea* sp., and *Spondylus* sp. from the writer's collection. He remarks: "The form identified as *Inoceramus* sp. is somewhat suggestive of *Inoceramus labiatus* Schlotheim of the Eagle Ford shale, and for this reason I should regard the containing chalk as more likely to be the typical Austin chalk than one of the higher chalks of Taylor age." Microscopic examination of the chalk, by Miss Lane, revealed a Taylor microfauna. The microfauna identified by A. L. Selig, both from the top and base of the chalk is upper Austin with a microfauna similar to that in the shales below the Blossom sand at Ben Lomond, Arkansas, which were considered by Dr. Stephenson as of Austin age. No Pecan Gap chalk has been found.

Navarro shales have been identified over an area of about 300 acres north of the salt works and of the southernmost Annona chalk. Those shales probably almost completely encircle the lake, but sand washed from the Wilcox mantles the shale lowlands. A fossiliferous locality was found by Hopkins of the south end of the lake. Lower Navarro fossils from the *Exogyra cancellata* subzone of the *Exogyra costata* zone were identified by Dr. Stephenson.

Midway shales crop out on the Palestine road midway between the Eagle Ford locality and Little Saline. They undoubtedly surround the dome on the inside edge of the circular drainage.

The Wilcox group surrounds the dome and is very steeply tilted

away from the center. Most of the outcrops are on the inner side of the outer row of hills and the dips ¾ mile from the center of the uplift vary from 20° to 30°. The steepest are on the outer side of the inner row of hills and a dip of 57° was found by Hopkins southeast of the lake.

The Wilcox consists here as elsewhere of sandy clays with sands and lignites and thin ironstone concretionary beds. No calcareous beds have been observed. At the lignite mine 1¼ miles northeast of the lake the three beds of lignite, each 7½ feet thick, are separated by 25 to 30 feet of sandstone and shale. A limonitic sandstone filled with casts of pelecypods occurs 45 feet above the highest lignite. This bed outcrops in a branch 300 feet northeast of the mine. The dip is 11° N. 80° E. The fossil casts have been identified by Dr. Julia A. Gardner of the United States National Museum, as: *Venericardia planicosta* Lamarck, *Cardium* sp., cf. *C. hatchitigbeense* Aldrich. *Corbula* sp. ind., *Bulliopsis* sp. cf. B. *choctawensis* (Aldrich), *Turritella* sp. cf. *T. pleboides* Vaughan. The age is probably upper Wilcox (Carrizo).[1]

The Mount Selman formation consisting of fossiliferous glauconitic sands overlain by iron ore, forms high hills 3 miles from center of the dome which have been slightly affected by the uplift according to Hopkins. Chapman, on his unpublished map of the dome, shows the lignite which is being mined and a similar bed on the south side of the dome to be highest bed in the Carrizo sandstone.

Underground geology.—Salt wells have been drilled on the northeast, west, and south sides of the lake. The shallowest salt is found at 122 feet in a well located a few hundred feet south of the Woodbine sand ridge. It is equally shallow on the west side of the lake in the well nearest the lake. The cap rock of gray, hard limestone, increases rapidly in thickness from 9 feet at the western shore of the lake to 32 feet in the wells farthest away. On both sides of the lake several wells have found very thin cap rock and have formed craters. The formations above the cap rock are sand and shale, either recent wash deposits or subsided Eocene sediments. On the east side of the lake the salt and shale were too intimately mixed for the brine to be

[1] See J. A. Gardner, "Fossiliferous Marine Wilcox in Texas," *Amer. Jour. Sci.*, Vol. 7, 1924, pp. 141–45.

used. Other wells were drilled nearly as far east as Little Saline and they encountered salt at 200 to 225 feet, but the salt was not overlain by a water sand and the cost of pumping water into the wells was too great. The well farthest northeast was drilled 560 feet and found only streaks of salt. A well drilled in 1923 in the small valley south of the lake was abandoned at 700 feet without finding the main salt core. Wells a few hundred feet north found the salt at the normal depth. Two wells were drilled through the salt and found it about 400 feet thick, but they did not go deep enough to determine the possibility of deeper salt.

Wells are drilled to the cap rock, at 120 to 160 feet, casing is set, and then the well is deepened 100 to 250 feet in the salt. Water from a water sand under the cap rock flows into the wells, dissolves the salt, and the brine is forced by compressed air to the plant. One well produced salt for 20 years, but others have caved where the cap rock is thin. Production in 1924 was obtained from two wells drilled in 1923 at the south end of the lake.

The well on the west side of the lake, one location south of the northernmost well, found sufficient cap rock underlain by water sand ("salt sand") to be a good producer as shown by the following log, although the northernmost well had no cap rock.

Feet (depth)	
18	Surface sands and clay
58	Blue shale
64	Sandstone
91½	Limestone
110	Blue shale
121	Blue shale and lime
122	Calcite
161	Blue shale
167	Salt
197½	Blue shale
199½	Gypsum
211½	Salt sand
406	Salt

The output of salt is normally 120 tons daily. It is shipped in barrels, weighing 280 pounds and in sacks. Assuming a production of 100 tons daily since 1904 gives the amount of salt produced as

500,000 tons or a bulk sufficient to permit the surface to subside as much as 2 feet over an area of $\frac{1}{2}$ square mile.

The normal stratigraphic sequence may be judged from the Brooks-Auld No. 2 well near Keechi dome described above.

Structure—Underthrusting.—Palestine and Keechi domes exhibit complex faulting which can be accurately mapped only after very careful study. One of the faults is well exposed in the railroad cut northeast of the salt works. The faulting at Palestine is more complex than that shown at the surface in other domes and it represents a series of underthrusts arcuate in form of blocks of formations older than the Wilcox with repetition of outcrop of the Austin chalk and Navarro formation (Fig. 12). The thickness of the Upper Cretaceous section is about 3,200 feet, and slices from four formations, some of which must have risen 5,500 feet, are exposed in a horizontal distance of less than 1,000 feet. About 1,500 feet of Eocene has also been removed from the center of the dome. The presence of salt directly beneath the Washita outcrop illustrates the force of the thrust of the salt core $1\frac{1}{4}$ miles in diameter shattering the intruded strata and thrusting shreds of several competent beds through 3,000 to 5,500 feet in height and over an area 30,000 feet in diameter.

The salt core as well as the region in general has suffered extensive erosion. It may originally have sheared its way completely through the Cretaceous and have stood far above the level of the present lake with other shreds of Cretaceous since removed by erosion.

Study of the distribution of the Cretaceous and of the underthrusting at Palestine dome will prove that the amount of uplift of Cretaceous formations cannot be measured with the same facility as the amount of uplift of the Wilcox which surrounds the dome. Underthrust shreds of deeply buried formations may be carried upward long distances by the salt and may be thousands of feet above the point where the upturned edges of the formation completely encircle the salt core. This condition applies at Brooks and Keechi as well as at Palestine domes. Were it not for underthrusting the Navarro might be the oldest formation exposed at any dome. The apparent scarcity of the Midway may be due to underthrusting and squeezing (diapirism) of older formations past it.

BUTLER SALT DOME

LOCATION AND HISTORY

Butler or West Point salt dome (Fig. 13) is located near the southeastern corner of Freestone County 3 miles east of the settle-

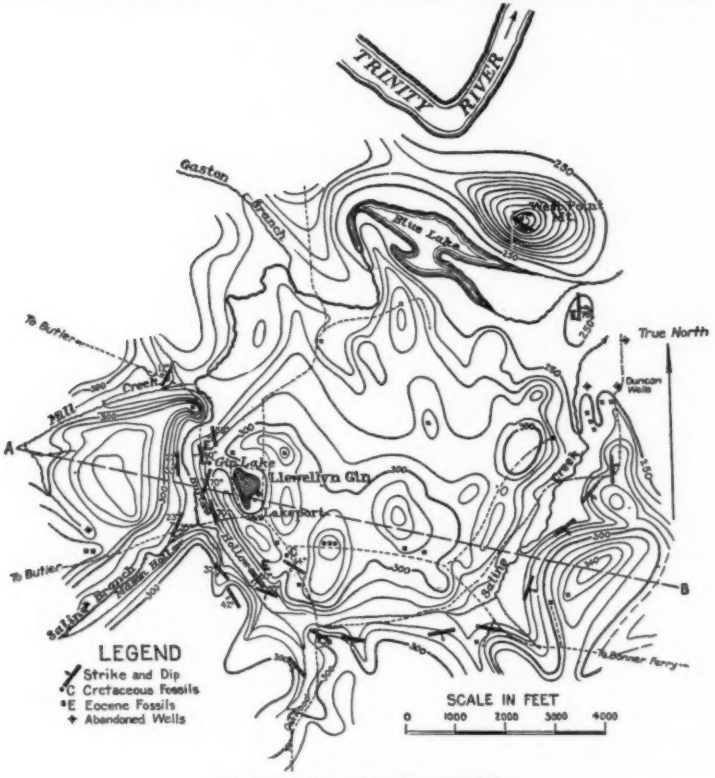

FIG. 13.—Topographic map of Butler salt dome showing a perfect example of a circular "race track" of barren saline prairie surrounding the dome. Radial drainage and springs supply the circular drainage. Llewellyn Gin Lake is a sink hole above the salt at the western edge of the salt core.

ment of Butler, 6 miles north of Oakwood, in Leon County, and 4 miles west of Bonner's ferry across Trinity River. It is near the eastern end and extends across the south line of the Simon Sanches

league No. 3. The name Butler, given by Hopkins, is from the nearby settlement and should not be confused with a settlement in Bastrop County by the same name. Neither is a post-office. West Point, the name given by Woodruff[1] and by DeGolyer, refers to a landing on Trinity River northeast of the dome when east Texas rivers were navigable. This name is lost except in local legend and is duplicated by a post-office in Fayette County.

Palestine dome is 6 miles northeast of Butler dome; Trinity River flows through the syncline between them, approaching within half a mile of Blue Lake, then making a conspicuous bend around the eastern side of Butler dome. The river is antecedent to the latest uplift of these domes.

Butler dome is topographically and geologically a type example of a salt dome with a central hill or mound surrounded by circular drainage in the form of a barren, saline "race track." Llewellyn Gin lake is on the west side of the central hill. The outer rim of hills is similar to that at Palestine dome, but the area affected by the uplift is probably only $3\frac{1}{2}$ miles in diameter whereas at Palestine dome it is over 4 miles. The central salt core lies within the row of hills inside the "race track" and the diameter of the salt is probably 1 mile.

Salt has been evaporated in small quantities at the broad saline in the northeastern quadrant of the dome. The wooden curbings of the shallow wells dug to collect the salt water are still visible.

Several wells have been drilled to a shallow depth in search of oil as described below.

TOPOGRAPHY

The barren saline "race track" which surrounds Butler dome surpasses in extent and continuity that of any other dome. Circular drainage outlines Palestine dome and circular drainage with salines outlines Price's dome in Louisiana, but groups of trees separate the salines on Price's dome so that the circle is not completely barren. The diameter of the circle at Price's dome is slightly over $\frac{1}{2}$ mile, at Butler dome almost $1\frac{1}{2}$ miles. In both domes the drainage divide in the circle is so low and the sand covering the saline is so wet that it is imperceptible except in the driest weather.

[1] E. G. Woodruff, *Bull. Southwestern (Amer.) Assoc. of Petroleum Geologists*, Vol. 1, 1917, p. 81.

Within the "race track" is the central "hill," or "mound"; a series of hills at Butler, a single hill at Price's. Sink holes are found on the hill in each dome; Llewellyn Gin Lake at Butler, and several small, dry sink holes at Price's. The maximum relief within the circle at Butler is 80 feet, at Price's 60 feet.

Outside the "race track" a rim of hills with steep slopes toward the saline surrounds Butler dome. Their relief is 70 to 80 feet above the saline, the same as the relief of the inner hill, with the exception of a monadnock of calcareous sandstone, called Rocky or West Point Mountain, which has a relief of over 100 feet. The other hills are composed of Wilcox sandy clays and outcrops are found along the base of the hills behind the line of springs.

Drainage of Butler dome is by Burton Hollow on the west and Saline Creek on the east, both emptying into Trinity River on the northeast. Burton Hollow, the larger creek, is fed by numerous springs and by radial branches flowing toward the dome. The source or the drainage is a gully on the Oakwood road and tributary branches are Saline Branch flowing through Mason Hollow, Mill Creek, and Gaston Branch Saline Creek rises in the saline prairie and is fed almost entirely by springs. Burton Hollow on the north empties into Blue Lake, a wide flat area covered by a shallow lake most of the year. Elevations with reference to sea level have not been determined in this region, but the assumed elevations on the map, Figure 13, must be approximately correct.

SPRINGS AND MOUNDS

Springs of fresh and of mineralized water characterize salt domes and commonly wells in the center of domes find undrinkable water. Contrary to usual conditions, water in shallow wells at Llewellyn Gin is potable. Salt, sulphur, iron, and alum are the minerals usually associated with the water. Many springs seep from the edges of the hills surrounding the saline "race track," others rise on the surface of the saline. Some have no pool of water, others form minature mud volcanoes, still others form pools of water surrounded by quagmires of unknown depth. One of the largest mineralized springs on interior salt domes is a strong sulphur spring in the center of Vacherie dome, Louisiana, where the sulphur odor permeates the

surrounding woods. An important sulphur spring occurs at the foot of West Point Mountain near Blue Lake.

The origin of the water in most of the springs and in the sandy surface of the saline is from upturned water-bearing sands. Salt water sands are found at shallow depths in the Coastal Plain and the uplift and erosion of the domes truncates these sands and permits artesian flows. Strongly mineralized water usually rises through joints, fissures, or faults, from greater depths. Many salines not connected with structural uplifts derive their salty water from normal impregnation of salt in certain Eocene horizons.

Mounds, of the type well known in the Coastal region, are abundant on Butler dome. They vary in size from a few feet to 100 feet in length and breadth, in height from a few inches to 4 feet. The best example on any interior dome is a newly formed mound northeast of Blue Lake and southeast of West Point Mountain. In 1923 it was 2 feet high and 6 feet in diameter with sharply curved sides and a flat top. It was composed of yellow clay dry on the outer two inches but plastic beneath so that the mound could be shaken like a bowl of jelly. A pole could be pushed down for over 10 feet in the center and the mud squeezed the pole out again, yet no water ran out of the mound. Most of the mounds at this dome are formed by creep of water-saturated clay below springs on the edge of the saline, but the new mound and many others nearby rise on the flat saline and are caused by springs carrying more or less gas.

GEOLOGY

Surface geology.—The oldest known formation at Butler dome consists of clays which weather black or yellow in color and which contain a few rolled Cretaceous fossils. These are found with a few score small phosphate nodules at one place in the side of a gully southwest of the junction of the Bonner Ferry and Oakwood roads. These have been identified by Dr. Stephenson, as previously described by the writer, as of Upper Cretaceous age.[1] The microfauna is Cretaceous according to A. L. Selig. Rolled fossils and phosphate nodules occur also in the Navarro clays north of Barrett and Greenwood well No. 1, on Keechi dome, and therefore the Butler clays are

[1] *Amer. Jour. Sci.*, Vol. 49, 1920, p. 128.

probably of Navarro age. The center of the dome seems to be capped with red Wilcox sandy clays which obscure other outcrops.

The fossils collected in 1919 were *Cucullaea* sp., *Exogyra* sp., *Trigonia* sp., and *Cardium spillmani* Conrad (?). In a collection made in 1924 Dr. Stephenson and Dr. Julia A. Gardner identified *Inoceramus* sp., *Exogyra* sp., sharks teeth, and fragments of ammonites.

Above the Navarro and on the inner rim of Burton Hollow between the two roads to the southwest of Butler a bed of concretions which stands up conspicuously from the surrounding shales carries fossils of Midway age identified by Dr. Stephenson. They are obtained most easily near the north road from a few concretions in which the original shale has not been impregnated with limonite or contorted by cone-in-cones. Dr. Julia A. Gardner has published a list of 40 fossils from this locality.[1] The adjacent shales contain an upper Midway microfauna identified by A. L. Selig. The same bed of concretions can be traced around the southwest quadrant of the dome and can also be found southeast of West Point Mountain and northwest of the Duncan wells.

Typical Lower Wilcox (Indio) red, gray, and chocolate colored sandy clays containing limonite concretions and lignite beds form the hills surrounding the circular saline. The chocolate or lavender shales carry leaf impressions. The race track is eroded in the lower portion of this sandy shale series and the symmetry of the race track is caused by the circular outcrop of the same easily eroded bed.

Plant impressions were collected by O. B. Hopkins and also by F. B. Plummer in the lower part of the calcareous sandstone of Carrizo age which forms Rocky or West Point Mountain north of the dome. The locality is near the eastern end of the mountain. These collected by Hopkins have been identified by Berry as of Wilcox age.[2] This sandstone which is identical in appearance with the "limestone" at Steen Saline, was quarried in 1870 and used for the railroad abutments over Trinity River. Carrizo sandstone is not

[1] "New Midway Brachiopod, Butler Salt Dome," *Amer. Jour. Sci.*, Vol. 10, 1925, pp. 134–38.

[2] E. W. Berry, *U. S. Geol. Surv., Professional Paper 131:* The forms are *Mespilodaphne coushatta* Berry?, *Palmocarpon butlerensis* Berry, *Proteoides wilcoxensis* Berry, *Sophora repandifolia* Berry?, and *Calatoloides eocenicum* Berry.

recognized elsewhere around this dome except in the bank of Trinity River at Bonner's ferry.

Underground geology.—Six shallow wells in search of oil have been drilled on and around the dome and their location is shown on the map, Figure 13. Three are on what was formerly the J. M. Duncan farm on the northeast side of the dome and were drilled to depths of 200, 700, and 1,220 feet, respectively. None of them reached salt. Two of them flow fresh water. A well was drilled at Llewellyn Gin and the casing may still be seen. It reached salt at about 312 feet and was abandoned in it at about 1,200 feet. Two wells were drilled west

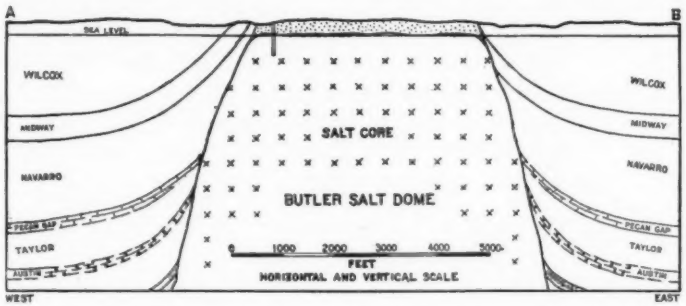

FIG. 14.—Cross-section of Butler salt dome from west to east along the line *A–B* of Fig. 13 with the salt core represented as an almost cylindrical plug.

of the gin on the Cornwell farm to a depth of about 700 or 900 feet. Artesian water flows from the southernmost of the Cornwell wells.

Only a few deep wells have been drilled in this vicinity. The Mike Healy test on the McDaniel farm near Butler, 5 miles west of the dome, reached a depth of 4,000 feet, but the log does not record chalk near the base. The Keechi Petroleum Company well on the McKinnon farm, John Carson survey, in Leon County, 12 miles southwest of the dome, was completed with cable tools. The log reports chalk from 3,943 to 4,003 feet which is probably Pecan Gap. The Sun Company Worthy well at Donie had a chalk at 3,185 feet which may be Pecan Gap and stopped in Austin chalk at 4,186 feet. If these correlations are correct the normal section at Butler dome would have Pecan Gap chalk at about 3,900 feet, Austin at 4,900 feet, and Woodbine at 5,800 feet.

Structure.—The quaquaversal dips surrounding the dome have already been described. The steepest are 70° on the hills inside Burton Hollow. Those on the inner side of the outer rim of hills vary from 20° to 55°. The ferruginous sandstone on Rocky or West Point Mountain dips 17°. Faulting has not been observed and the uplift seems to be very regular.

The diameter of the circular saline is 7,500 to 8,000 feet, of the salt core 1 mile, and that of the area uplifted by the doming is probably $3\frac{1}{2}$ miles. The edges of the salt core are probably steeply inclined as shown in Figure 14 because the area uplifted is not as great as at Palestine. If the oldest beds exposed by normal upturning are of Navarro age the amount of their uplift is about 2,500 feet. The lack of exposures within the outcrop of Cretaceous shales may indicate slight solution and subsidence of the top of the salt core besides that at the Gin lake. The red Wilcox soil now covering it may have washed in over either the Cretaceous or the dissolving salt, probably over the latter.

FURTHER NOTES ON THE ORIGIN AND NATURE OF THE CURRIE STRUCTURE, NAVARRO COUNTY, TEXAS

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ABSTRACT

Developments in the Mexia fault zone since January, 1923, have shown that the several oil and gas pools in this zone are bounded on the west by distinct faults which overlap one another in a definite manner. The conditions attending these faults suggest that torsional stress operated in their orlgin.

In the producing fields the faults have been found to be relatively complicated. Correlation of logs in the Currie pool, described here as an example, shows that more than one fault is involved in the displacement, and that this local fault zone dips more steeply in the Austin chalk and Woodbine sand than in the softer Eagle Ford shale.

The relation of the deep Woodbine or "Morrow" pay at Currie is considered.

In January, 1923, the writer published a paper on the Currie field, Navarro County, Texas.[1] Since then the limits of this field have been more closely defined, the deep "Morrow pay" has been discovered (in the spring of 1923), and we have learned more about the conditions existing not only in this pool, but also in other similar fault structures of the Mexia type. The time seems ripe for presenting some of the new aspects of this subject.[2]

The reader is reminded that the principal oil sand in the Currie field is encountered in the Woodbine formation, about 50 feet below the base of the Eagle Ford shale. Above this horizon, at the top of the Woodbine, there is a thickness of about 350 to 380 feet of Eagle Ford shale, overlain by approximately 420 feet of Austin chalk, and this, in turn, by some 2,100 to 2,500 feet of Taylor, Navarro, and Midway formations, the first two of Upper Cretaceous age and the last of Eocene age. Below the main pay of the Woodbine formation is a series of sandstones and shales. Many of the sands show a little oil or gas, but only one, the "Morrow pay," 250 feet

[1] *Amer. Assoc. Petroleum Geologists, Bull. 7, No. 1,* pp. 25–36.

[2] The writer wishes to express his appreciation to Mr. Leon Pepperberg for suggestions and conferences in reference to certain details of correlation in this study.

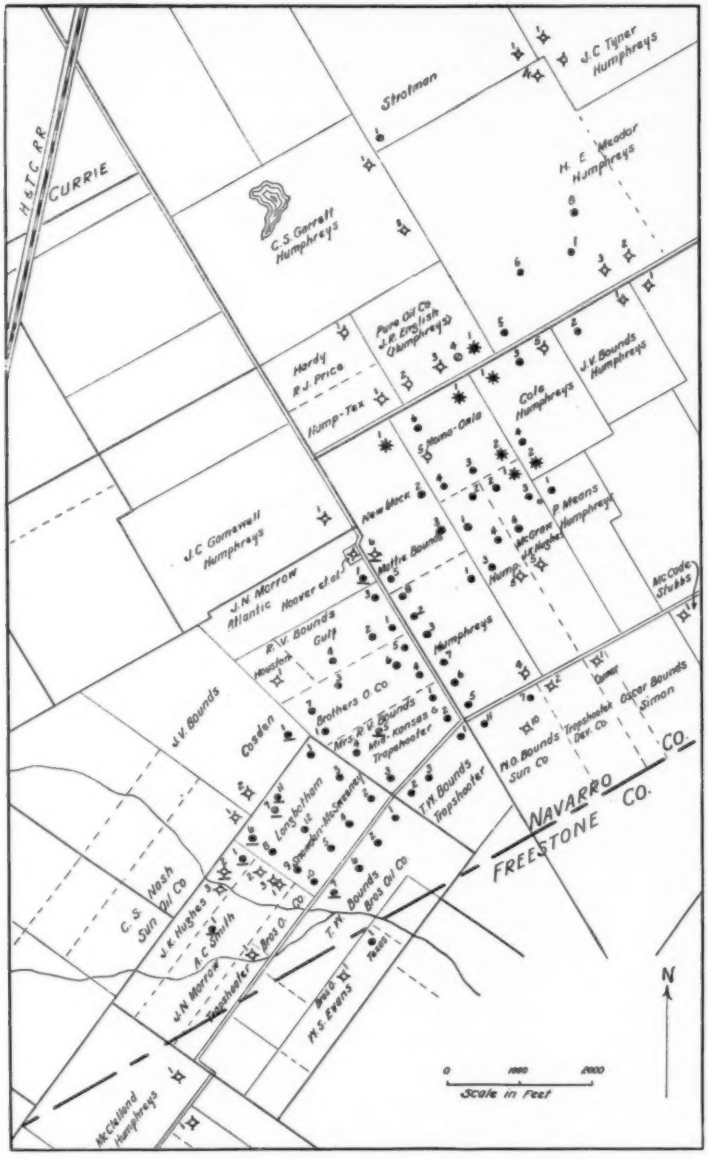

FIG. 1.—Map of Currie field showing leases and locations of wells and dry holes. underscored wells have been drilled to the Morrow pay.

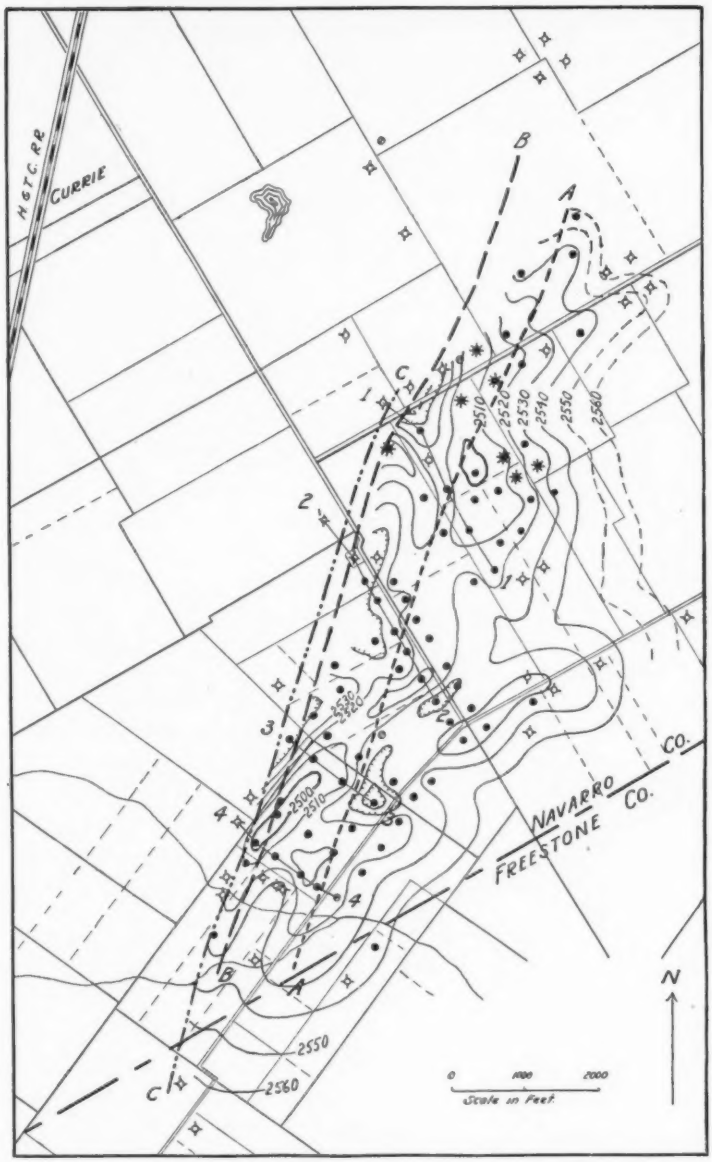

FIG. 2.—Structure of the Currie field. Contours represent depth of top of main pay below sea-level. *AA*, *BB*, and *CC* are lines where fault cuts top of Austin Chalk, top of main pay, and top of Morrow pay, respectively. 1, 2, 3, and 4 are lines of sections shown in Figs. 3 to 6.

below the main pay, has made commercial production and even this from only three or four wells.

When our former paper on Currie was published, we thought the chances were in favor of there being one irregular fault connecting Currie and Mexia, and probably continuing for many miles northward; but subsequent development has proved that each pool is associated with its own major fault, and that these faults apparently overlap one another, the southern end of each lying west of the northern end of the next one to the south. From a genetic point of view, this relationship is very interesting since it indicates that the origin of the Mexia fault zone involved warping or twisting—torsional stress rather than simple tension. The axis of warping may be assumed to have been north and south or somewhat west of north and east of south. The torsional stress seems to have produced (1) tensional forces acting about at right angles to the Mexia fault zone and causing the great normal faults of that zone, and (2) compressional forces acting roughly parallel to the zone and buckling the strata, particularly against the big faults where the resistance of the beds to folding was weakened by the breaking. Thus it appears that, in each of the producing fault structures in the Mexia zone, both the big fault, bounding the field on the west, and the moderate buckling of the strata in the upthrown block on the east, may have been contemporaneous effects of the same general causes.

Locally, in the several producing fields, the faults have been found to be more complicated than was at first supposed. In more than one instance, in the Powell field, and also subsequently in the Wortham field, drilling returns have been lost, and attempts to plug off bottom water have resulted in the complete disappearance of considerable quantities of such materials as cotton seed, etc. This means that in some parts of the fault zone there are open channels of large size. Cores secured while drilling show that the rocks have been severely brecciated and sheared, and they have demonstrated, further, that the width of the zone in which such fracturing has occurred is sometimes many feet. From a practical standpoint, a very interesting condition, now proved to exist in several of the fields, is a lowering of the dip of the fault where it

passes across the Eagle Ford shale. On account of this feature, the producing area may extend as much as several hundred feet farther west than it would if the fault continued to have a uniform dip

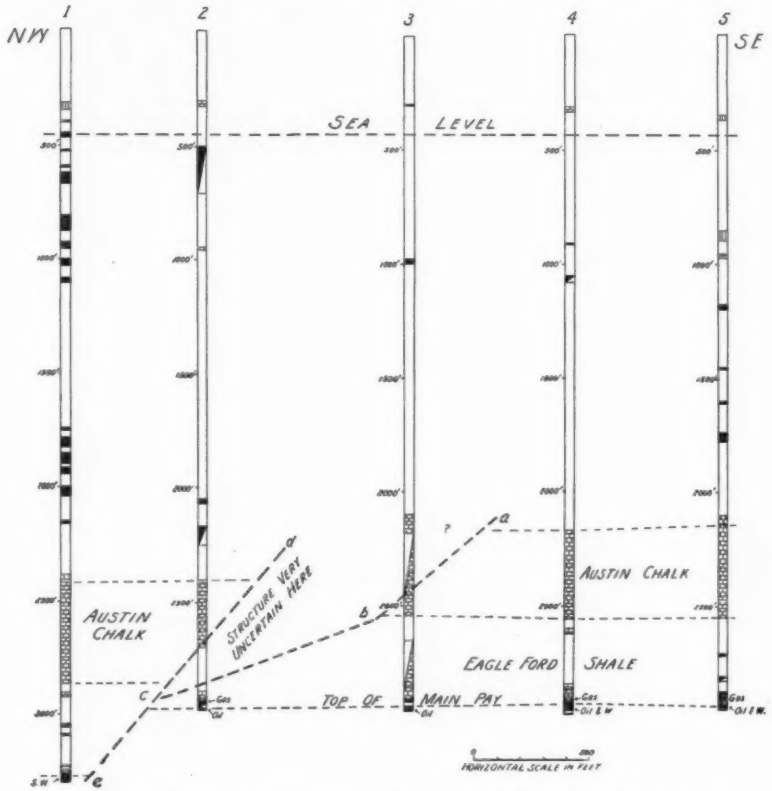

FIG. 3.—Log section along line 1, Fig. 2. Logs are records of following wells: No. 1, Humphreys-Mexia Price 1; No. 2, Homa-Okla McGaw 6; No. 3, *ibid.*, McGaw 4; No. 4, Humphreys-Mexia McGaw 1; No. 5, *ibid.*, McGaw 3.

downward from the top of the Austin chalk. It is this condition especially that we want to describe in the present paper.

Figure 1 shows the extent of the Currie field, the names of the leases, and the numbers of the wells. Both names and numbers have

been omitted from Figure 2 in order that the structural features may be brought out more distinctly.

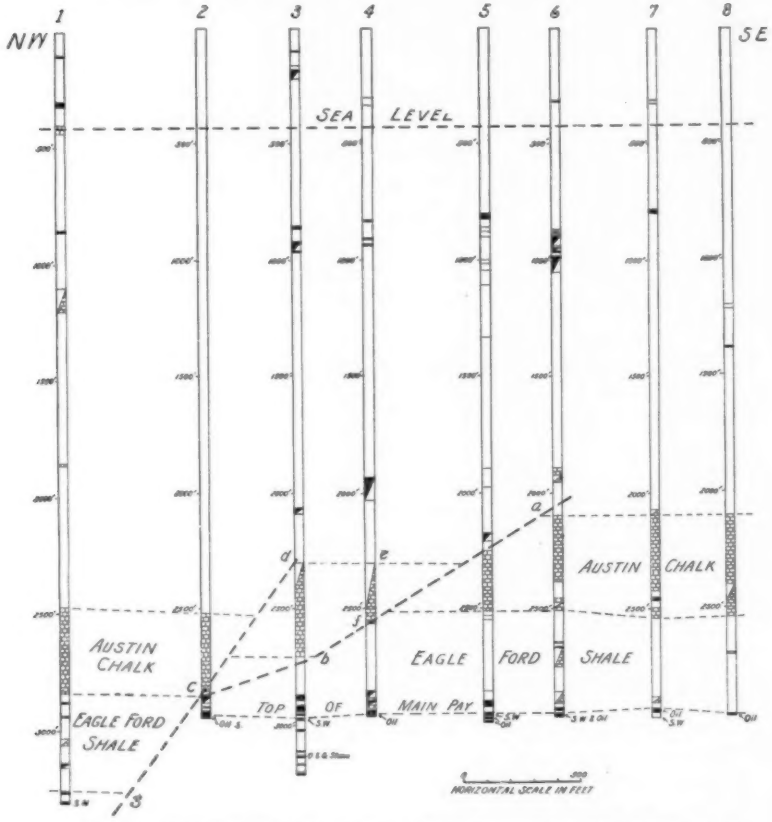

FIG. 4.—Log section along line 2, Fig. 2. Logs represent following wells: No. 1, Humphreys-Mexia, Gamewell 1; No. 2, Atlantic Oil Co., Church Lot 1; No. 3, Atlantic Oil Co., Morrow 1; No. 4, Gulf Production Co., R. V. Bounds 3; No. 5, *ibid.*, R. V. Bounds 1; No. 6, Bros. Oil Co., R. V. Bounds 5; No. 7, *ibid.*, R. V. Bounds 4; No. 8, Trapshooter Reilly, R. V. Bounds 1.

In Figure 2, *AA* is the approximate position of the major fault where it cuts the top of the Austin chalk (cf. Figs. 3–6). To the east of this line all well logs record the full thickness of the chalk and

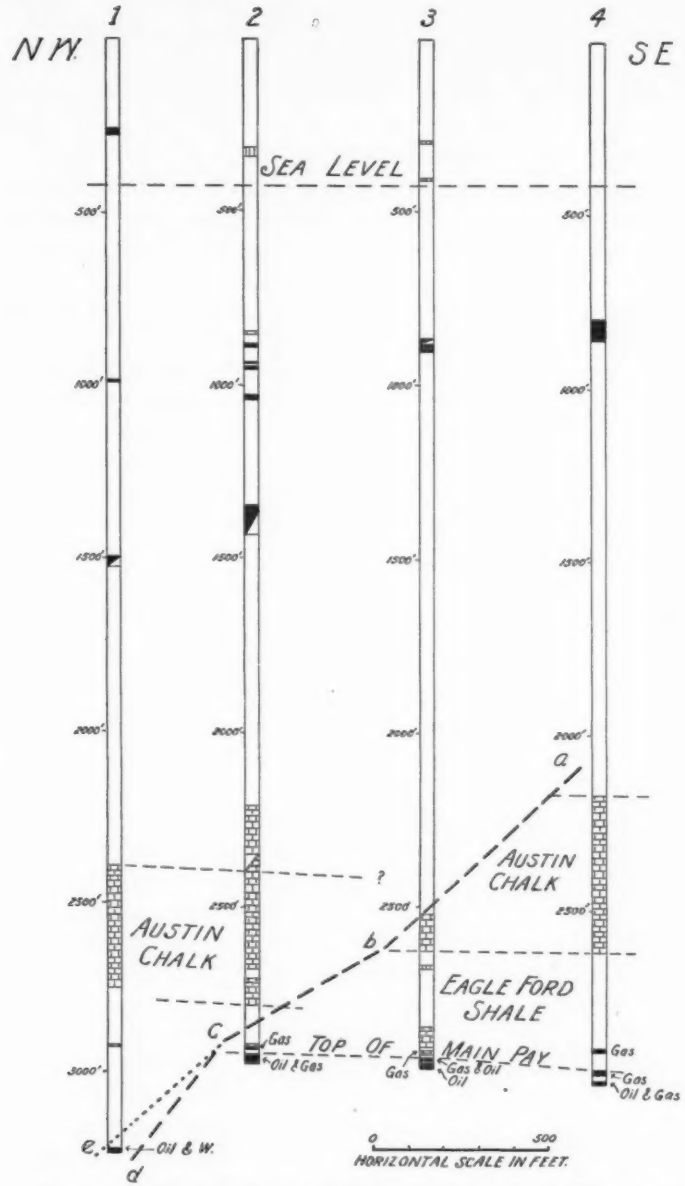

FIG. 5.—Log section along line 3, Fig. 2. Logs represent following wells: No. 1, Cosden Oil Bounds 1; No. 2, Snowden & McSweeney, Longbotham 1; No. 3, *ibid.*, Longbotham 3; No. 4, *ibid.*, Longbotham 2.

show it relatively high. West of *AA* the chalk is either thin, having had part of its thickness cut out by the fault, or it is of normal thickness, but low, in the downdropped block.

Line *BB*, in Figure 2, marks the position where the major fault, dipping west, intersects the main Woodbine pay sand, which is 50 feet below the top of the Woodbine formation. This is the western limit of production from the main pay.

Line *CC*, Figure 2, shows where the major fault cuts the Morrow pay, 250 feet below the main pay in the Currie field.

In Figure 3, we have a section showing the Austin chalk on the upthrown side of the fault in logs 4 and 5 and on the downthrown side in logs 1 and 2. Log 3 is very uncertain. Probably the base of the chalk, a little below 2,500 feet, is on the upthrown side. From the records here plotted the fault line could be drawn straight from the top of the chalk in log 4 to *c;* but this would be different from the structure as illustrated in other records in this zone. Consequently, we have shown the fault with a steeper dip from *a* to *b* than from *b* to *c*. Since the upper Woodbine, at the bottom of log 1, is in the downthrown block, with approximately the normal thickness of Eagle Ford and Austin chalk above it, the fault must dip more steeply between *c* and *e* than farther east. Apparently the basal part of the chalk is cut out in log 2. Therefore, we must conclude that there is a fault *dc*, as well as fault *abc*. For simplicity, we have shown *dc* and *ce* as one and the same fault.

In Figure 4, logs 5 to 8 inclusive, have the chalk on the upthrown side of the fault, and logs 1 and 2 record the chalk definitely on the downthrown side. In log 5 the top of the chalk has been cut off by a fault which must have a dip low enough to cross log 3 near *b*. On the assumption that *d* and *e* mark the top of the chalk in logs 3 and 4, the fault *ab* has a displacement of about 200 feet. Its dip decreases west of *b*, since it crosses log 2 at *c*. Its dip from *b* to *c* is not over 20°. In logs 1 and 2 another displacement is indicated, suggesting a fault from near *d* to *c*. As in Figure 3, we have drawn this fault continuing straight to *g*, to the east of log 1 which does not reveal signs of being cut by the fault as deep as the well was drilled. The displacement of this second fault is about 200 feet, thus making a total displacement of 400 feet for the Currie fault zone.

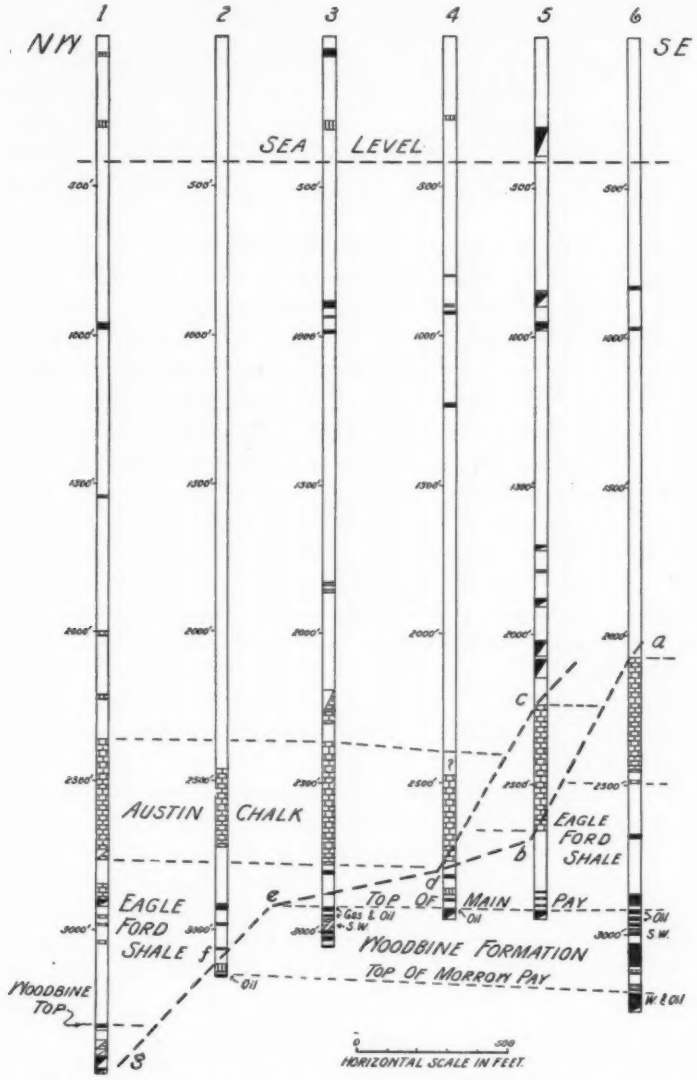

FIG. 6.—Log section along line 4, Fig. 2. Logs represent following wells: No. 1, Sun Oil Co., Nash 1; No. 2, Snowden & McSweeney, Longbotham 6; No. 3, *ibid.*, Longbotham 8; No. 4, *ibid.*, Longbotham 9; No. 5, *ibid.*, Longbotham 10; No. 6, Bros. Oil Co., T. W. Bounds 7.

The relations illustrated in Figure 5 are not certain. The fault might be drawn straight from the top of the chalk in log 4 to a point near *e*, but we believe the interpretation given is more in harmony with the conditions found in neighboring wells. Probably the fault steepens, as at *cd;* we have no proof, however, against its passing through *e*.

Figure 6 is perhaps the most instructive section. Log 6 is the only one showing the formations below the Taylor marl with normal thickness and on the upthrown side of the major fault. The well of which log 5 is a record must have been cut by a fault at the base of the chalk at *b*, unless the log is entirely wrong. This would indicate the presence of a steep fault, *ab*. Another steep fault, *cd*, is needed to drop the chalk to the position shown in logs 1 to 4, inclusive. If 5 is a poor log, one fault only might exist between *a* and *d*. In either event, whether we assume faults *ab* and *cd*, or a single fault which would pass from *a* to *d*, the total displacement is about 350 feet and the dip of the main fault must decrease from *d* westward to a point somewhere near *e*. The angle of the dip of this part of the fault, where it crosses the Eagle Ford shale, is less than 20°. Beyond *e* the fault must steepen considerably, since it cuts log 1 below the top of the Woodbine.

Logs 2 and 6 were drilled to the Morrow pay. The former is a record of the Hughes Morrow No. 1 well, the discovery well of this pay zone. It had an initial production of 5,000 barrels. Commercial production, to date, has been obtained from this pay only just east of the fault. Several wells, like that recorded in log 6 (Fig. 6), have had good showings but have not been completed as successful wells.

In glancing at Figures 3 to 6, the reader will no doubt conceive of other interpretations. We realize that there are many ways in which the faults might be drawn. We have attempted to choose the simplest method of explaining the conditions reported in the logs. Following are the conclusions which seem to us of chief importance:

1. The main faulting, associated with the Currie structure, more or less brecciated and sheared the Austin chalk and Eagle Ford formations in a zone several hundred feet wide. We do not possess

sufficient data to know whether the same may be said of overlying and underlying formations.

2. The total displacement due to this faulting seems to have been from 350 to 400 feet in the Currie field. This displacement is always a sum total of two or more faults, but apparently not the measure of any one fault.

3. When determinable, the dip of the main fault or faults is relatively steep in the harder formations (Austin chalk and Woodbine formation), but is often remarkably low in the less resistant Eagle Ford shale.

4. The complex of structural conditions in the Mexia fault zone is such as to suggest that the faulting and also the associated slight bending of the strata were common effects of regional torsional stress.

MAY, 1925

THE JENNINGS OIL FIELD, ACADIA PARISH, LOUISIANA[1]

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Houston, Texas

ABSTRACT

The Jennings oil field was one of the earliest oil fields of the first class on the Gulf Coast. It is on a dome in Tertiary sediments. Although the salt has not been drilled into, limestone which has never been drilled through and which resembles cap rock underlies the main part of the field, and is taken to indicate the presence of a salt dome. There is a surface mound that is probably the remnant of a salt dome mound and a depression that in part is probably a "central depression." The Jennings field has been one of the most prolific of the Gulf Coast oil fields, and had many long-lived wells with enormous total production.

INTRODUCTION

LOCATION

The Jennings oil field, known also as the "Mamou," or "Evangeline" oil field, is located in Acadia Parish in southern Louisiana, 185 miles west of New Orleans, and 175 miles east of Houston, Texas. It is 35 miles east of Lake Charles, and 7 miles northeast of the town of Jennings on the Southern Pacific Railroad. The field is near the center of T. 9 S., R. 2 W. The field is reached by auto from the towns of Jennings or Crowley.

HISTORY

The Jennings oil field is one of the oldest oil fields of the first rank in the Gulf Coast. Attracted by the escape of gas in springs which had long been known by early settlers, the Jennings Oil Company, early in 1901, engaged the Heywood Brothers of Beaumont to drill a test well, to be located in Section 46 near the northeast corner of a block now known as the Gulf Refining Company's Jennings-Clemont lease. In August of 1901, eight months after the famous Lucas well at Spindletop came in, the Jennings well encountered a loose sand at 1,882 feet (564 m.), and blew in spraying oil and sand in considerable quantity; after blowing wild for several hours, the well choked up and was

[1] Published by permission of the Rycade Oil Corporation.

[2] Chief Geologist, Rycade Oil Corporation, Houston, Texas.

[3] Geologist, Rycade Oil Corporation, Houston, Texas.

finally abandoned. The next test, the Southern Oil Co.'s No. 1, was unfortunately located far to the south of the real field and was abandoned below 2,500 feet (750 m.), without finding oil. Profiting by this experience, the Southern Oil Company located their next test 250 feet northwest of the original Jennings Oil Company's No. 1. At a depth of about 1,850 feet (555 m.), this well also encountered a loose broken sandy formation, blew in, and made considerably more oil than No. 1 Jennings Oil Company but not having a screen soon choked up and was lost.

The field now needed no further recommendation; extensive exploration was quickly started; and within the next few months several producers were completed. It was not, however, until June, 1902, that the first really successful well was brought in, the Jennings Oil Company No. 2, also drilled by the Heywood Brothers, and located 100 feet (30 m.) southwest of their No. 1, the pioneer test of the field. The field produced slightly over 548,000 barrels (73,060 tons) of oil during 1902.

From then on the producing territory was gradually extended in every direction. In 1903, the Superior Oil Company extended the field westward, and the Crowley Oil Company extended it to the north and east, but wells drilled on the hill and far out from the field were dry..

In January 1904, the Chicago Jennings well No. 2, extended the field to the south; also in this year the Producers Oil Company on their 40-acre Latrielle tract extended the field to the southeast. Operations increased steadily until in February, 1904, Jennings had 35 producing wells. Over 6 million barrels (833,300 tons) of oil were produced in the last six months of that year.

The next year, 1905, was discouraging in many respects. As a consequence of the reckless waste of gas and the correspondingly diminishing gas pressure, many of the older wells had to be put on the pump, and salt water made its appearance in the older wells. To make matters worse the flood of oil from the great Humble field caused a slump in the price of crude to 16 to 18 cents per barrel.

The peak of production for the Jennings field, nevertheless, was reached in 1906, with a production for the year of over 9 million barrels (1,250,000 tons). Production declined rapidly in 1907, and again in 1909, and then gradually, until the present daily average is about 500 barrels (69 tons) per day for the field.

From time to time, periodical increases in production take place in the old field and systematic exploration for flank sands may yet revive the activity of the field. The recent renewed attempts to find deeper oil have been unsuccessful. On the north edge of the field in Section 48, the Coastal Oil and Fuel Company drilled to 4,302 feet (1,336 m.) and failed to find oil. Recently the Rycade Oil Corporation on the southeast side of the field abandoned their well at 2,355 feet (706 m.) in caprock.

PHYSIOGRAPHY

REGIONAL PHYSIOGRAPHY

The physiographic province in which the salt domes of Louisiana and Texas occur is the Gulf Coastal Plain (Fig. 1). In southern Louisiana and southeast Texas, it is composed of the Coastal Prairie,

FIG. 1.—Physiographic sketch map of the Texas Louisiana gulf coast, showing the position of the Jennings Field.

the Kisatchie Cuesta, other cuestas farther inland, and the Mississippi Valley and Delta. This physiographic province has been discussed, and its component features have been described elsewhere by the senior author.[1]

The Jennings salt dome lies about midway of the Coastal Prairie

[1] Barton, Donald C., "The Pine Prairie Salt Dome," This *Bulletin*, Vol. 9 (1925), pp. 739–42.

belt. The area immediately around the dome has been much dissected by the rivers, Bayou Nezpique, Bayou Cannes, which unite just below the dome to form Mermentau River. To the east and to the west of that area, is a broad flat prairie which belongs to one of the intermediate Pleistocene plains, perhaps the Hammond. The dome itself, is on a narrow strip of prairie between Bayou Nezpique on the west, and Bayou Cannes on the east. The crest of this interstream ridge seems probably to be a remnant of the prairie level of this region.

PHYSIOGRAPHY OF THE DOME

The topography at the dome consists of a broad, shallow, irregular basin-like depression which is drained by a brook and its ramifying branches, and of a low, irregular hill to the east. The basin is about 1½ miles in diameter and covers a large part of the richly productive area in the center of the field as well as a much larger area of much poorer productive territory to the west. The origin of the basin may be explained by erosion, by collapse due to solution of the top of the salt dome, or by settling consequent upon the extraction of the oil. It is certain that there has been erosion. The basin was considered by Harris to be one of the central depressions characteristic of salt domes. It is very much larger and more ill-defined than the typical central depressions of salt domes and on the west extends well off the probable area of the salt. There seems to be a fair possibility, however, that the basin is in part a salt-dome of central depression. According to reports of an observer familiar with the field, the basin in considerable part has been caused by settling since the field came in. Non-instrumental evidence based on casual observation and memory cannot be accepted as conclusive, but the reported observation is decidedly suggestive, especially in the light of the results of an investigation of the Goose Creek field by one of the Gulf Coast oil companies.[1] On the basis of a priori reasoning, it seems reasonable to expect distinct settling of the surface in the noncap-rock oil fields of the first class.

(1) Sediments such as the Gulf Coast oil sands are laid down

[1] Wallace E. Pratt and Douglas W. Johnson, "A Recent Local Subsidence of the Gulf Coast of Texas," *Geol. Soc. of Amer. Proceedings* (preliminary list of abstract of papers), Thirty-eighth Annual Meeting, 1925.

with an excess of pore space, that is, the individual grains are not fitted together in such a way as to give the minimum volume and minimum pore space. In the case of finer sediments, and less so in the case of the coarser sands laid down under water and never dried out, the individual particles or grains must be held apart in some degree by the included water. (2) Compression of the sediments can take place only to the amount of the expulsion of the interstitial fluids. (3) In buried sediments, there must be a tendency toward expulsion of the interstitial fluids and compression of the sediments under the weight of the overlying beds. (4) But in the case of the Gulf Coast beds, this tendency must be greatly hindered by the fact that the sands tend to be lenses in a predominant massive clay-shale section. (5) In the case of the Gulf Coast oil sands which are Tertiary in age, and therefore, not of great geologic age, it seems reasonable to expect that the beds have a potential capacity for shrinkage consequent upon the withdrawal of the interstitial fluids. (6) Contemporaneously with the extraction of fluids from within the productive area and the immediately surrounding drainage basin, a tendency should be set up for flowage inward from the whole surrounding region. This flowage, however, can take place only slowly through fine, silty sands, such as those at Jennings, and will be yet further retarded by the lensing and faulting of the sands, and cannot keep pace with the relatively free extraction of oil and water through the wells. The column of sediments, therefore, should shrink to the extent of the difference between the volume of water and oil that flows in and the volume that is extracted. (7) If the assumption is made that the field has produced twice as much salt water as oil, and if the fluids are withdrawn from an area four times the productive area, the oil and salt water extracted if spread over that total drainage area would have a thickness of a magnitude of 50 feet (15 m.) vertically.[1]

[1] Total production of field equals 46 million barrels (6,388,000 tons) of oil = 1,930 million gallons = 7,277.8 liters = 7.8 million cu. meters. If production of salt water is twice that of oil, total volume of fluid = 23 million cu. meters. Production came from an area 2,000 feet (600 meters) square = 0.36 million sq. meters. If fluids are drawn from an area four times as large as productive area, drainage area = 1.5 million sq. meters. If extracted fluids were spread evenly over drainage area, they would cover it to a depth of 15.3 meters, or 50½ feet.

The settling necessary to account for the basin is 7 to 10 feet. The shrinkage in the sediments would be spread over 300 feet of section, about 40 per cent sand, and would represent a contraction of volume of the whole zone to the extent of 3 to 4 per cent, or a contraction of the volume of the sands to 7 to 8 per cent. In view of the magnitude of withdrawal of fluids, it seems to the senior writer that there is warrant for consideration of the theory of the formation of the eastern portion of the basin in part at least, through settling consequent upon the extraction of the oil and salt water.

The low hill on the Arnaudet and Latreille tracts on the east edge of the oil field would seem probably to represent the remnant of a salt dome mound. It is irregular in shape with a N.NE.–S.SW. axis, and a SE.–NW. axis. It rises 13 to 16 feet above the general level of the prairie west of the oil field and 8 to 13 feet higher than the general prairie level for 3 to 4 miles to the north. As it rises so definitely above the normal level prairie level, the hill seems to be an obscured salt dome mound.

GEOLOGY

SURFACE GEOLOGY

The beds exposed at the surface at Jennings (Fig. 2) are Pleistocene sands, sandy clays, and clays. In southeast Texas and southwest Louisiana a division of the Pleistocene beds is possible into the Lissie sandy member on the north and the Beaumout clayey member on the south. Farther east in Louisiana this distinction is not so clear; the Beaumont clay becomes much sandier, and toward Opelousas, Lafayette, and Abbeville it becomes decidedly loess-like. The Jennings dome lies in the vague zone between the Lissie and the Beaumont. The beds exposed at the surface over the dome seem to be those normal to that region.

SUBSURFACE GEOLOGY

The Texas and Louisiana Gulf Coast oil fields are associated with two main types of geologic structure: the salt dome type as at Spindletop, and the non-salt dome type as at Goose Creek. Although salt has never been actually encountered in the field, Jennings seems probably to be of the salt dome type.

Salt domes are characterized by quaquaversal dipping sediments

around a central salt core. A mantle of caprock, in many cases, immediately overlies the salt core. The shape of the central salt core may be elliptical in plan as in the case of Stratton Ridge, or, more commonly, nearly circular as at Spindletop. The diameter of the

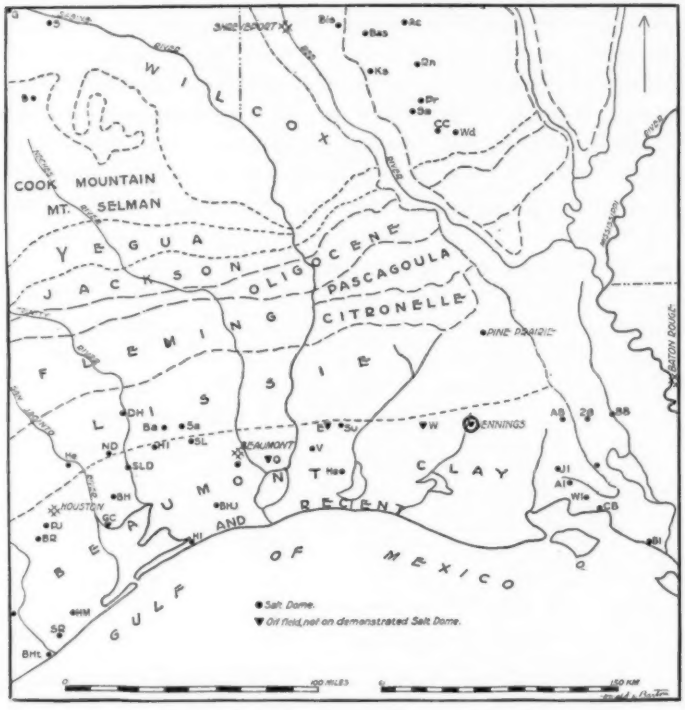


FIG. 2.—Geologic sketch map of Louisiana and southeast Texas

salt core varies: where the core is elliptical, the major diameter may be as much as 12,000 feet (3,600 m.), and the minor diameter two-thirds as much, as at North Dayton; where the core is circular, the diameter is from 2,500 feet (750 m.) as at New Iberia, to 3 miles (5 km.) as at Humble. The thickness of the salt core of the domes is as yet unknown. At Humble the top of the salt is around 1,400 feet (425 m.), and the Texas Company's Wheeler Pickens well was abandoned

at 5,410 feet (1,623 m.) still in rock salt. The depth from the surface to the salt varies from a few feet, as at Avery Island, Louisiana, to some 2,300 feet (690 m.) below the surface, as at Markham. The top of the salt is commonly nearly flat and the edges are nearly vertical. In many of the Coastal oil fields, the salt is topped by a mantle of cop rock of varying thickness, size, and shape. It is often very porous and even cavernous. In some cases, it yields large amounts of oil as at Spindletop, or it may be entirely devoid of oil, as at Damon Mound. The thickness of the cap rock varies from a few feet to 1,000 feet (300 m.), or more. The strata surrounding the salt core are, for the most part, loose, unconsolidated sediments, and dip in all directions from the salt core.

The cap rock and the somewhat characteristic doming seem to indicate that Jennings belongs to the salt dome, or Spindletop type of oil field. The salt has not yet been drilled into, and is not actually known to be present. But no wells rightly located to encounter the salt have been drilled deep enough to prove, or disprove its presence. The data available in regard to the cap itself are rather scanty. The following wells encountered the cap:

Very slightly south of the center of the field:
Producers Oil Co.'s Houssiere Latreille No. 74, at 2,012 feet....603 meters
On the southeast side of the field:
Rycade Oil Corp.'s Houssiere Latreille No. 1, at 2,355 feet....706 meters
(Abandoned in cap.....at 2,660 feet....798 meters)
Producers Oil Co.'s Houssiere Latreille No. 81, at 2,398 feet....719 meters
On the south side of the field:
Producers Oil Co.'s Houssiere Latreille No. 101, at 2,600 feet....780 meters
On the southwest side of the field:
Gulf Rfg. Co.'s Jennings-Heywood No. 40, at 2,693 feet....808 meters
On the east side of the hill: an unnamed well at the north edge of the Houssiere-Latreille tract is some times spoken of as having gone into the cap at around 2,200–2,300 feet (700 m.). The writers, however, have not been able to confirm this report. Since no well has been drilled through it, the thickness of the cap is not known. From the depth to which the Rycade Oil Corporation's Houssiere Latreille No. 1 was drilled into it, the cap is more than 300 feet (90 m.) thick.

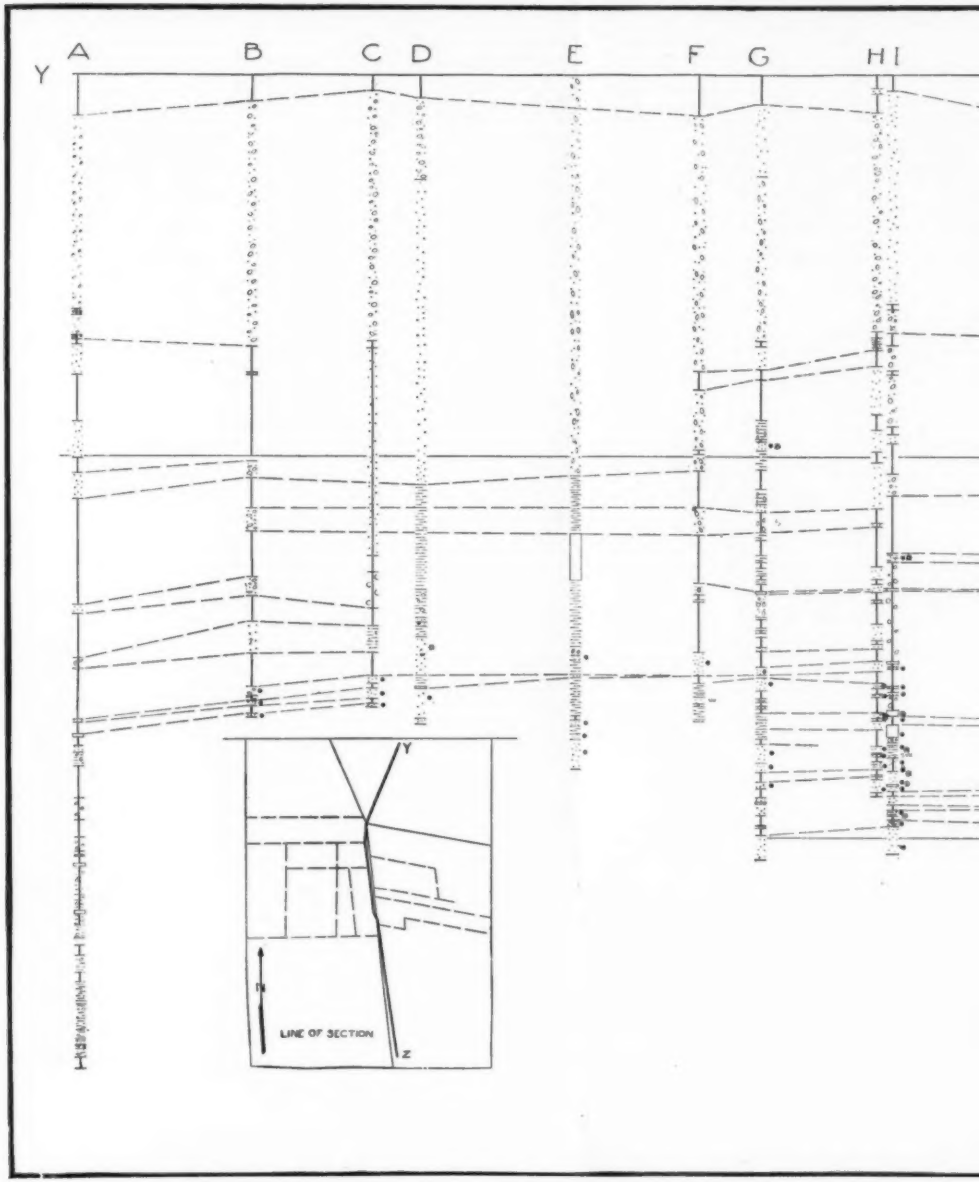
The lithology of the cap is not well known. Until our own well, the Rycade Oil Corporation's Houssiere Latreille No. 1, went into it, we could get no authentic information in regard to the character of the cap, and in that well only a few cores were taken in the cap. The

upper part of the cap seems like a disintegrated granular limestone. When the driller went into it, he logged it as sand and in the Producers Oil Company's Houssiere Latreille No. 81, it was apparently logged as sand without being recognized. A core from a depth of 2,393 feet (727 m.) was composed of a soft, very friable, finely granular limestone. It was finely banded with alternating black and white bands, 1 to 4 cm. thick. A core from a depth of 2,426 feet (737 m.) was of limestone very similar to that of the preceding core, except in not being friable, and in being much harder. It is not known whether the limestone is underlain by a gypsum cap.

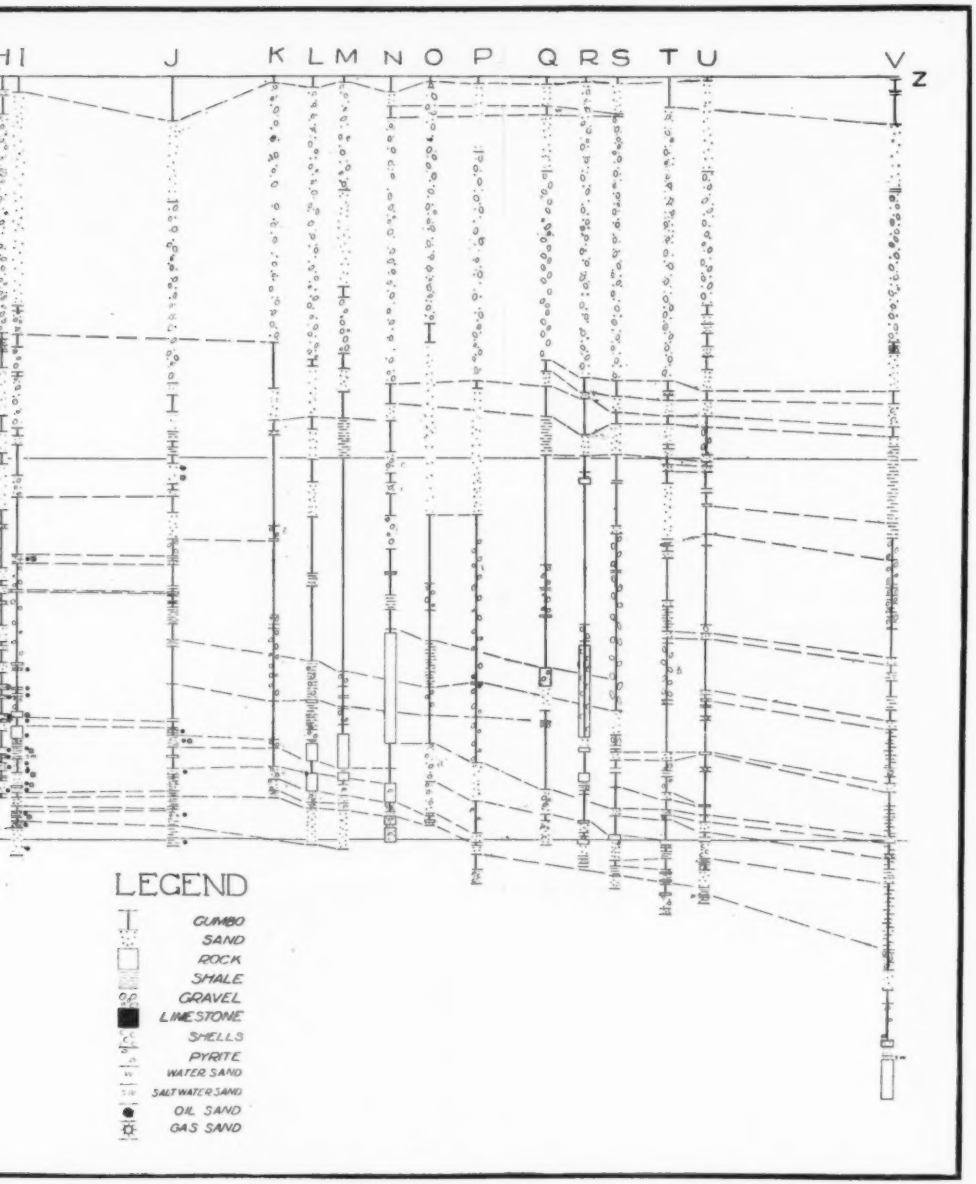
The extent of the cap is indicated by the negative control on the north of the Coastal Oil and Fuel Company's well drilled in Section 48 to a depth of 4,342 feet (1,320 m.) without encountering the cap, and on the southeast by the Rycade Oil Corporation's Houssiere Latreille No. 2, which encountered the cap at 3,395 feet (1,034 meters and a recent well which encountered the cap at ca. 2,717 feet (828 m.) in Block 6 in the SW. $\frac{1}{4}$ SW. $\frac{1}{4}$, Sec. 46.

The structure of the Jennings oil field was inferred by Harris on paleontological grounds to consist of a rather sharp, double-crested, structural dome, located about on the western 1,500 feet of the line between the Arnaudet and the Houssiere Latreille tracts. His inferences were drawn largely from the distribution of *Rangia johnsoni* in the wells. On the northwestern of the two crests, this fossil was found at a depth of 1,025 feet (307 m.), although 200 feet (60 m.) to the south, it was not encountered until below a depth of 1,940 feet (582 m.). On the basis of this distribution Harris drew in structure contours showing a dip of about 80 degrees on the south side, and of 45 degrees on the north side. On the southeastern crest, the upper limit of *Rangia johnsoni* was 1,300 feet (390 m.), and on both the north and south sides of the crest, Harris gives structure contours showing a dip of about 75 degrees.

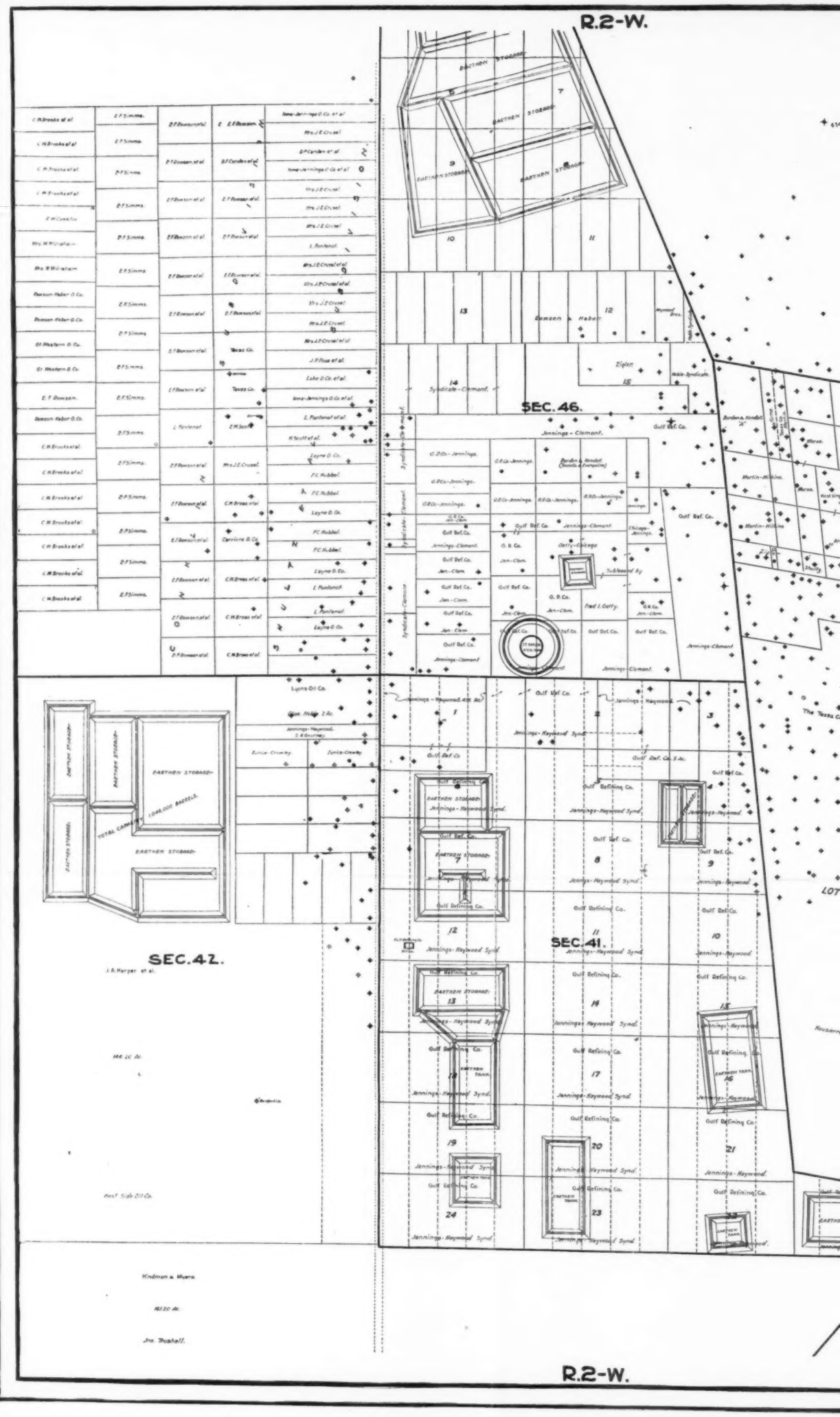
The presence of any such sharp doming in the subsurface beds at Jennings seems doubtful from the results of subsurface correlation, from the structure of the other domes, and from a priori reasoning. Graphic sections, with closely spaced wells, were drawn up by the writers as follows: a north-south section (Plate 2) along the west line of the Arnaudet and Houssiere Latreille tracts; two east-west, a



Graphic well log section across the f



across the field from north to south


R.2-W.
SEC. 46.
SEC. 41.
SEC. 42.
EARTHEN STORAGE
Jennings-Clement.
Jennings-Haywood Synd.
Gulf Ref. Co.
Gulf Refining Co.
Ramsen & Haber
Ziglar
Syndicate-Clement
Lyons Oil Co.
Kindman & Myers
Jno. Pushoff.
R.2-W.

SEC. 48.
Coastal Oil & Fuel Corporation
(Crowley Oil & Mineral Co.)
Arnaudet
Gulf Refining Co.
Arnaudet Plant
Rycade Oil Corp.
Houssiere-Latreille
T. 9 S.
Franklin Oil & Min. Co.
Houssiere-Latreille 5 Ac.
The Texas Co. 40 Ac.
Rycade Oil Corp.
Texas Co. 20 Ac.
SMITHS ACRE
Houssiere-Latreille 10 Ac.
Rycade Oil Corp.
SEC. 47.
ANTHONY
COCHRAN
GRANT.
LOT No 1.
LOT No 2.
LOT No 3.
LOT No 4.
LOT No 5.
LOT No 6.
LOT No 7.
LOT No 8
EARTHEN STORAGE
Houssiere-Latreille
Rycade Oil Corp.
Houssiere-Latreille 7.5 Ac.
(Exchange Agreement)
MAP OF
JENNINGS FIELD.
ACADIA PARISH LOUISIANA.
SCALE: 1" = 200'

north-south, and a northwest-southeast section in the west 40-acre lot of the Houssiere Latreille tract, and an east-west section along the south line of Section 48 (Crowley Oil and Mineral Company's lease). The best section that could be drawn east-west through the location of the suspected structural crests was fragmentary, and unsatisfactory. Although lithologic well-to-well correlation of graphic logs is rather unsatisfactory as a rule in the Gulf Coast, and is not to be given implicit credence, fairly satisfactory correlation was possible on all of these sections except the one through structural crests reported by Harris. No key bed is present that can be traced with confidence completely across any one of the sections, but there are several massive sands, especially in the top of the predominantly clayey zone extending from 1,000 feet (300 m.) downward and in the main productive zone. Moderate doming of a magnitude of 300 to 500 feet (90–150 m.) seems to be indicated by the correlation of the wells on these sections. The crest of the dome coincides approximately with the two crests reported by Harris and the doming extends at least to the edges of the field. The dip shown by the top of the cap checks the moderate doming shown by the correlation of the beds above it. From the Producers Oil Company's Houssiere Latreille No. 74, to the Rycade Oil Corporation's No. 1, the slope of the top of the cap is 26 in 100 and from the latter well to the Producers Oil Company's No. 101, the slope is about 16 in 100. No data are available in regard to the cap rock in the area covered by the two crests of the dome found by Harris, but as the wells in that area produced from depth of 1,700 to 1,900 feet (510–570 m.), the cap rock if present cannot be less than 1,900 feet (570 m.) below the surface. The Producers Oil Company's Houssiere Latreille No. 74, however, is immediately at the south edge of the northwestern crest, and the rather moderate gradient on the top of the cap is known to come directly to the edge of the sharp crest of Harris. Although it has not been demonstrated that structures similar to those of Harris are not present, no such fold is known on the other Gulf Coast salt domes. The salt cores themselves have equally steep dips on their flanks, and in some cases the edges of the lateral beds have been dragged up by the salt until they have similar dips, but in no case is such sharp doming known to exist in the Tertiary sediments by themselves. If

the competence of unconsolidated sands and clays is considered, it is questionable whether it would be possible for a frustrate cone of such sediments, 1,500 feet across the base and a 1,000 feet high, to

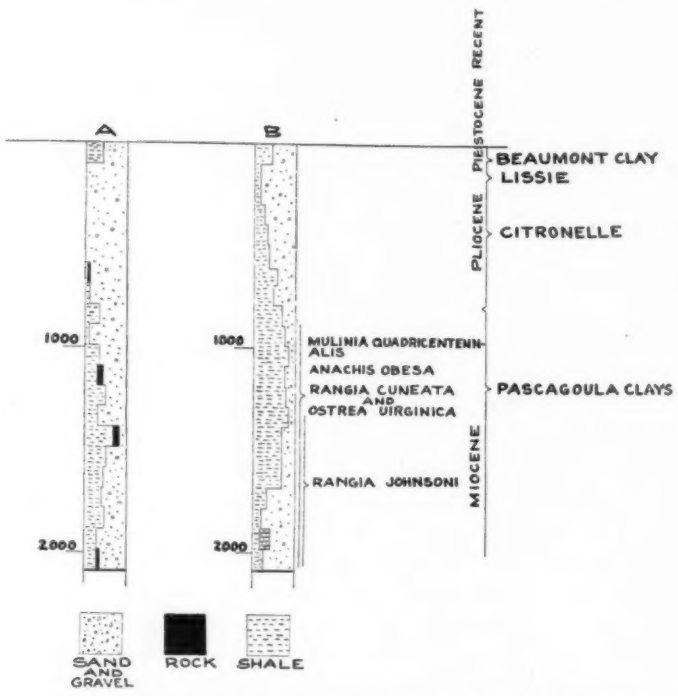


FIG. 3.—Graphic composite logs: (*A*) At edges of field (Crowley O. & M. Co. Nos. 20, 21, 22, and 23. Gulf Ref. Co.'s Clement Nos. 27, and 28, and Prod. O. Co.'s Houssiere Latreille No. 10). (*B*) At center of field (Prod. Oil. Co. Houssiere Latreille Nos. 1, 8, and 9; Teche Oil Co. Latreille No. 1, and Crowley Oil & M. Co.'s Houssiere Latreille No. 15).

be intruded into overlying sediments. If there should be a tendency for any such intrusion of any such cone of these sediments, the latter should tend to yield, rather than transmit the thrust rigidly, unless either the resistance to the intrusion were very slight, or the internal mechanics of the intrusion were the same as in the intrusion of a salt

dome. Neither of those special conditions, however, can be called upon to explain the situation at Jennings.

STRATIGRAPHY

The section in the center of the Jennings field (Fig. 3) is shown in the following tabular summary:

GEOLOGIC SECTION IN THE CENTER OF THE JENNINGS FIELD

	Feet	Meters
Predominating clay	0 – 60	0–18±
Predominating sand with some gravel and clay	60±–850±	18±–255±
Clay 70 per cent; sand 30 per cent	850±–1,750±	255±–525±
Clay 30 per cent; sand 70 per cent	1,750±2,000±	525±–600±
Limestone cap	2,000	2,000

The range of the fossils in the central part of the field is given by Harris as follows:

DISTRIBUTION OF FOSSILS IN THE CENTRAL PART OF THE JENNINGS FIELD

	Feet	Meters
Mulinia quadricentennalis	1,100	330
Anachis obesa		
Rangia cuneata and *Ostrea virginica?*	900–2,000	270–600
Rangia johnsoni and *Amnicola* sp.	1,300–2,000	390–600
Mulinia quadricentennalis Cerithium sp.	1,850	555
Mulinia quadricentennalis	200	600

The section on the edge of the field is as follows:

GEOLOGIC SECTION ON THE EDGE OF THE JENNINGS FIELD

	Feet	Meters
Predominantly clay	0 – 90±	0– 27±
Predominantly sand with some gravel and clay	90±–1,100±	27±–330±
Clay, about 70 per cent and sand, 30 per cent.	1,100±–2,800±	330±–840±

In the only deep well drilled close in to the field, the Coastal Oil and Fuel Company's McDaniel No. 86, the section below 2,800 feet was as follows:

RECORD OF LOWER PART OF DEEP WELL NEAR JENNINGS FIELD

	Feet	Meters
Sand and rock	2,822–2,928	654– 890
Sand with thin beds clay	2,928–3,043	890– 925
Sand	3,043–3,182	925– 967
Sand with thin beds of clay	3,182–3,476	967–1,057
Sand	3,476–3,578	1,057–1,088
Sand and clay	3,578–3,856	1,088–1,172
Clay with some sand	3,856–4,181	1,172–1,271
Sand and clay	4,181–4,342	1,271–1,320

The conventional, normal stratigraphic section for southern Louisiana is as follows:

NORMAL STRATIGRAPHIC SECTION FOR SOUTHERN LOUISIANA

	Feet	Meters
Pleistocene:		
Beumont. Clays and sands, and loess Lissie. Sands and gravels (Unconformity)	1,500	455
Pliocene:[1]		
Citronelle. Non-marine, yellow and red sands and clays; gray where unweathered (Unconformity)	50–400	15–120
Miocene:[1]		
Pascagoula. Marine in part, blue, green and gray clays, locally calcareous, some layers of sand (Unconformity)	250–400	75–140
Oligocene:[1]		
Hattiesburg. Non-marine, blue and gray clay, some beds calcareous, thin beds of sand and sandstone.	300–350	90–105
Catahoula. Non-marine, gray sands, sandstones, fine conglomerates, clays	600–800	180–240
Eocene:[2]		
Jackson. Marine-gray sands and dark calcareous clays	100–160	30– 50
Yegua. Palustrine-gypsiferous sands and clays with lignite	400–800	120–240

That this conventional section is not readily applicable at Pine Prairie is shown by the fact that here the thickness of the section above the Catahoula is at least 3,500 feet (1,050 m.), and is probably

[1] After G. C. Matson, *U.S.G.S. Prof. Paper No. 98-L*, p. 172.

[2] After E. T. Dumble, "Geology of East Texas," *Univ. of Texas Bull. No. 1869*, 1920, chapter v.

over 4,500 feet (1,400 m.) instead of 1,400 feet (420 m.) according to the maximum figures of the conventional section. On the basis of lithology, the following correlation of the section at Jennings is possible:

LITHOLOGIC CORRELATION OF THE SECTION AT JENNINGS

	Feet	Meters
Clay zone, Beaumont clay	0– 90	0– 27
Sand zone, Lissie and Citronelle	90–1,100	27–330
Clay zone, Mainly Pascagoula (Miocene), possibly with some Citronelle (Pliocene) at the top and some Hattiesburg (Oligocene) at the base	1,100–2,800	330–840
Sand zone, Catahoula	2,800–?	(850)
Sand and clay zone, (?) Jackson	?–4,342	(1,320)

On the basis of megascopic fossils, Harris believed that the upper 2,000 feet, or possibly more of the section on the edge of the dome is Quaternary, and the beds immediately below, Miocene. Within the past three years a very considerable advance in the knowledge of Gulf Coast stratigraphy through micropaleontology has been made. However on examination of the samples from the Rycade Oil Corporation's Houssiere Latreille Nos. 1 and 2 showed no fossils. No examination of the samples from any other Jennings well has been made.

OIL AND GAS

INDICATIONS

The indications which led to the drilling at Jennings were the mound, and the gas seeps that had been long known about 600 feet north of the site of the first well. In these indications, the early pioneers saw all the earmarks of another Spindletop, but quickly discovered that the mound did not indicate the position of the oil. Within recent years, paraffin dirt has been recognized on the Arnaudet and Clement tracts. Sour dirt and oil seeps have not been reported.

Gas.—Not much gas was found. The upper 600 to 800 feet of the overlying section consisting of sands, gravels, and sandy clays, do not afford the necessary impervious strata for the accumulation of large amount of gas. The gas in only a few cases is found above the oil-bearing member. This fact is in large measure responsible for the rather low initial production and very low rate of decline of

wells which ultimately produced very large amounts of oil. The gas at Jennings appears to have the same poisonous, hydrogen sulphide content, characteristic of the gas at Batson and Spindletop.

Oil.—The oil field covers an irregularly elliptical area of about 300 acres centering around the northwest corner of the Houssiere Latreille tract, Section 47 (Plate 3). Nine-tenths of the production came from a circular area of about 120 acres in the northwest corner of the Houssiere Latreille tract, the west end of the Arnaudet tract, the eastern edge of Section 46, and the southwest corner of Section 48.

The depth of the oil "sands" ranges from 110 to 2,400 feet (33–730 m.). A small production of heavy black oil from small pumpers was obtained in the early days from depths of 110 to 150 feet (33–45 m.) on the south side of the field. The main productive zone was a series of fine, unconsolidated sands between the depths of 1,700 and 1,900 feet (515 and 575 m.). Shows of oil are reported not uncommonly to have been found at depths of around 1,000 feet (300 m.) but no commercial production was obtained from that depth. A few wells produced from depths between 1,600 and 1,700 feet (485 and 515 m.) and a number from depths of 1,900 to 2,100 feet (575–635 m.). Of the latter wells, a few were very good producers, as for example:

Crowley O. and M. Company No. 1, 4,000 bbls. (555 tons) from 1,915–1,965 feet (574–596 meters)

Heywood O. Company Crowley No. 1, 8,000 bbls. (1,110 tons) from 1,909–1,962 feet (572–595 meters)

Producers O. Company Clement No. 4, 5,000 bbls. (690 tons) from 1,916–1,966 feet (574–596 meters)

On the west side of the field productive sands were found down to depths of 2,400 feet (730 m.). No production was obtained from the cap rock. Deep lateral production has not been found, but the possibilities have not been well tested. On the north side of the field, the Coastal O. and F. company's No. 86 was drilled to 4,342 feet (1,319 m.) without obtaining production, and on the southeast side of the field, the Rycade Oil Corporation's Houssiere Latreille No. 2 is drilled to 3,489 feet (1,063 m.) without having obtained production.

Productive zones can be traced vaguely for considerable distance from well to well. It is difficult to trace individual "sands" even across short distances. A "sand," in many cases, seems to have been a portion of a much larger mass of barren sand from which it is not logged as having been cut off by any partings. The thickness of the sands is difficult of determination, but seems to range from 10 to 150 feet (3 to 45 m.), averaging 40 to 60 feet (12 to 18 m.).

PRODUCTION

The total production of the Jennings field for the twenty-two years, 1902 to 1923, inclusive, has been approximately 46 million barrels (6,388,000 tons). The rapid rise, and somewhat gradual decline of production compares most favorably with Spindletop. The maximum annual production of the Jennings field, 9 million barrels (1¼ million tons) in 1906, however, is only about half of the maximum annual production of the Spindletop field, 17 million barrels (2⅓ million tons) in 1902. The production of the Jennings field is shown graphically in Fig. 6.

With the exception of Humble and West Columbia, Jennings has had more big gushers than any other field of the Gulf Coast. The number and size of the gushers were as follows:

GUSHERS IN THE JENNINGS FIELD

Barrels	Tons	No. of Wells
4,000	550 per day I.P.	12
5,000	700	9
6,000	825	5
7,000	950	7
8,000	1,110	4
10,000	1,400	2
15,000	2,100	1
20,000–60,000	2,700–8,000	2
Very large but record lost		3
Total		45 wells over 4,000 bbls. per day initial production

Two wells in the Jennings field were distinguished by their large, steady output; Bass and Benkenstein No. 1 produced 1½ million

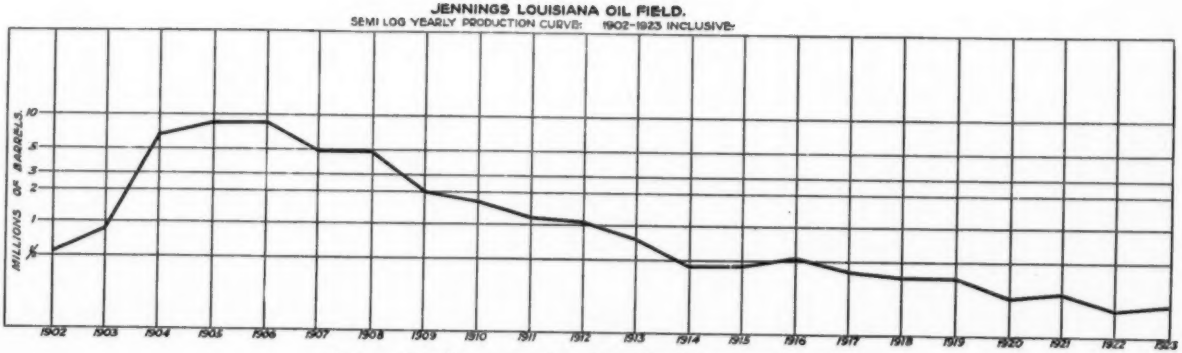


FIG. 4.—Semi-log curve of yearly production for Jennings Field

barrels (208,000 tons) of oil in 145 days from September 8 to January 31; and the Wilkens No. 2 produced one million barrels (138,000 tons) of oil in 82 days from November 20 to February 10 and made a total of 2½ million barrels (347,200 tons) before it finally quit producing. The Abrams No. 1 of West Columbia probably holds the record for the amount of oil produced in three months, but either the Bass and Benkenstein No. 1 or the Wilkens No. 2 probably holds the record for long continued high production, as both these wells had a daily production of less than 13,000 barrels (1,700 tons).

The per acre production of the Jennings field is one of the highest for any of the Gulf Coast fields (Figs. 4–6). The per acre production of the field as a whole is 153,000 barrels (21,000 tons). But as over 80 per cent, and probably 90 per cent of the production came from an area of about 120 acres, the per acre production of the main field is of the order of 300,000 to 340,000 barrels (41,000–47,000 tons).

Table I shows the variation in the temperature (?) and the gravity of the oil:

TABLE I

TEMPERATURE AND GRAVITY OF JENNINGS FIELD OIL

	Temperature		Gravity	Depth	
	F.	C.	Baumé	Feet	Meters
Gulf Production Co.					
Fee Simple No. 28	72	22	21	1545	470
Jennings Fee No. 2	80	27	23½	.....	.....
Syndicate Fee No. 29	80	27	20	.....	.....
Syndicate Fee No. 34	98	37	25½	2104	651
Jennings Clemont No. 12	72	22	21½	1575	479
Jennings Clemont No. 17	80	27	22	.....	.....
Jennings Clemont No. 16	68	20	23½	.....	.....
Arnaudet No. 14	70	21	21	.....	.....
Arnaudet No. 20	95	35	24½	.....	.....
Arnaudet No. 21	102	39	23½	1900	578
Morse No. 21	82	28	22½	.....	.....

These data are from gauger's observations. The low temperature looks suspicious, and it is probable that the three higher temperatures, 95°, 98°, and 102° C. are the most nearly correct. If the mean annual temperature of the ground at Jennings is taken as the same as the main annual free air temperature at Houston, the geothermal gradient is 58 feet per 1° F. (28.7 meters per 1° C.) for Arnaudet No. 21, and 73 feet per 1° F. (39.9 meters per 1° C.) for Syndicate

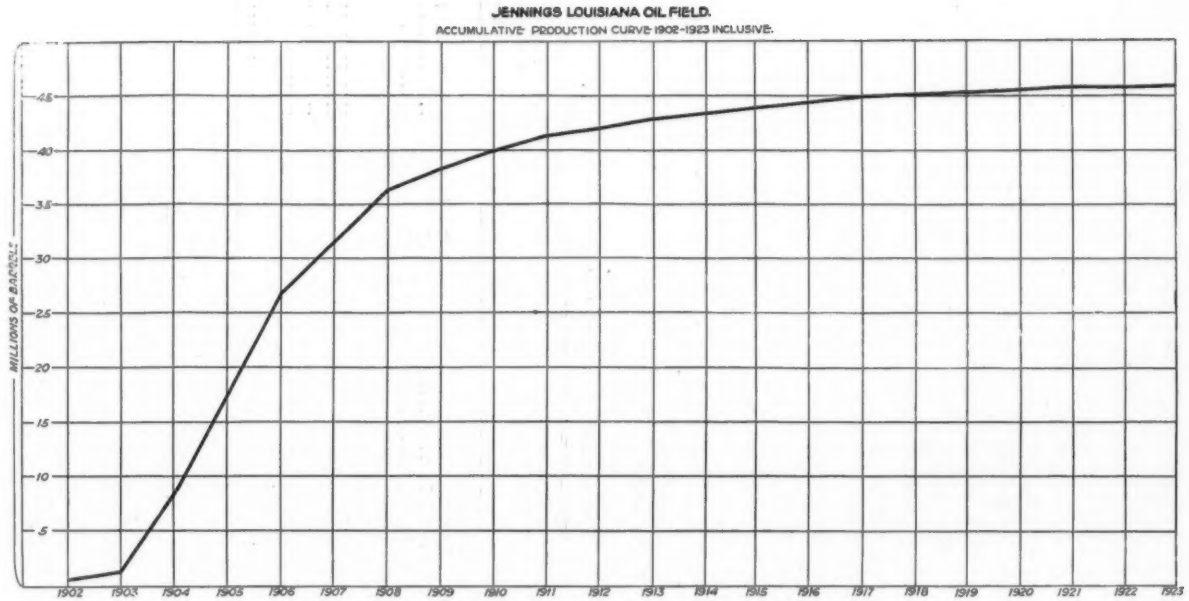


FIG. 5.—Curve of accumulative production for Jennings Field as a whole

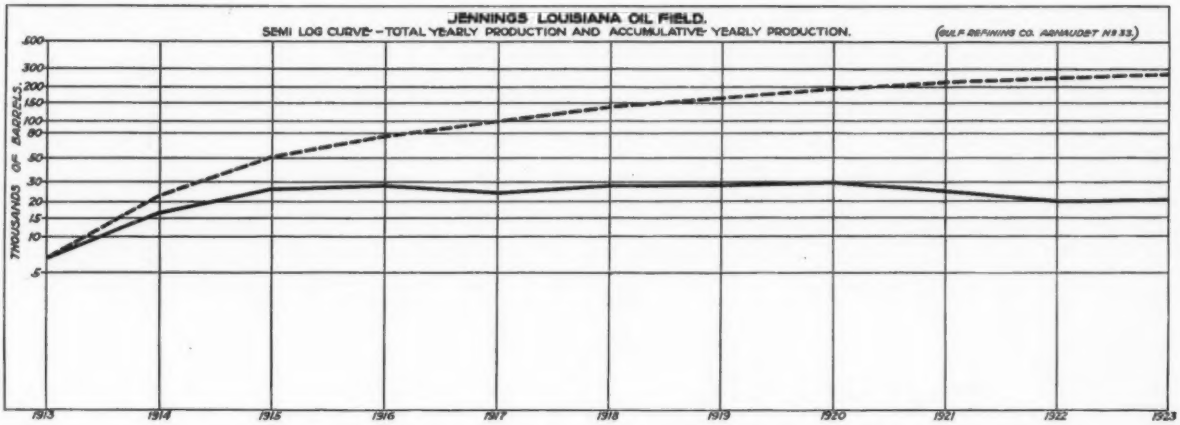


FIG. 6.—Semi-log curve of yearly and accumulative production for an individual well

Fee No. 34. This gradient is considerably higher than that at West Columbia, and is considerably lower than at Batson and Sour Lake.

The gravity of the oil shows a range of some $5\frac{1}{2}$ degrees Baumé. A suggestive relation of gravity with depth is revealed, if the gravity is plotted with depth:

DISTRIBUTION OF GRAVITY OF JENNINGS CRUDE WITH DEPTH

Depth Feet	Meters	Gravity Baume
1,545	470	20.8
1,575	479	21.6
1,900	578	23.4
2,104	651	25.4

A similar increase of gravity with depth holds in an interesting manner at Orange over a vertical zone of 2,500 feet. There the gradient is much lower, about 250 feet per 1° Baumé in comparison with about 100 feet per 1° Baumé at Jennings.

FUTURE OF THE FIELD

The field at present is nearly dead. In 1922 there were 5 completions; of these, 3 were producers and 2 were dry. The production can be increased slightly by cleaning out, resetting, or redrilling old wells, and by drilling strippers to small sands that were passed up in the early days. But under the present-day technique of oil recovery, the old productive area is essentially exhausted. There is a possibility that deep, productive sands will be found. The results, however, of the Coastal Oil and Fuel Company's No. 86 on the north side of the dome and of the Rycade Oil Corporation's No. 2 on the southeast side do not look auspicious for the finding of deep, lateral production. But the deep, lateral sands have not been sufficiently tested to be entirely condemned.

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GEOLOGICAL NOTES

AN INTERESTING VOLCANIC ASH FROM CALCASIEU PARISH, LOUISIANA

Recently there has come to the writer's notice an interesting volcanic ash or tuff from Calcasieu Parish, Louisiana, which because of its distinctive character, may be of interest to other students of subsurface geology of the Gulf Coastal Plain. Volcanic ash and glass have been reported from the later Mesozoic and Tertiary deposits of the Gulf Coastal Plain in numerous papers, but in few of these have any definite data been given concerning petrographic character. These deposits have been referred to as "volcanic glass," "rhyolitic ash," etc., but seldom has the index of refraction of the material been given. In the writer's opinion information concerning the petrographic character of these beds or deposits will probably make them of considerable value in correlation. When more data are assembled light may be thrown on the source of the material; the origin of which, as far as the writer has been able to determine, is at present purely hypothetical. Ash deposits, such as the one described in this paper, should lend some data to the solution of the problem, and to some extent aid in correlation. The paper is written with the hope that others will add to the too meager store of information. No one subsurface geologist unaided can hope to assemble all the data and work out a complete correlation between these beds of volcanic ash; possibly all working together cannot do so. The problem at least is an interesting one.

The writer has noted ash and minor amounts of glass in numerous cores from wells in the Gulf Coastal Province, but as yet time has not been available for the description of these. Some of these cores are composed almost wholly of ash, and may be of the same age and petrographic character as the one here described.

The present core is from a depth of 1,510 feet in the Duhig *et al.* No. 1 Levy in the Hayes district of Calcasieu Parish, Louisiana. The well is located as follows: S.W. $\frac{1}{4}$ of N.E. $\frac{1}{4}$ of Sec. 14, 11 S., 6 E.

As received in a wet condition, the core was light buff to light gray in color. On drying this changed slightly to a lighter gray and a very light brownish gray, depending on the amount of iron oxide coloring material present. Due to the fact that the core was received in an iron container, it is possible that most of the iron oxide was extraneous. The core was contaminated to some in taking, but chunks free from contamination showed the true character of the material.

When preparing the core for study the customary laboratory method used by the Gulf Production Company was followed. The sample was soaked and washed with a stream of water in a two-hundred-mesh sieve. Only material

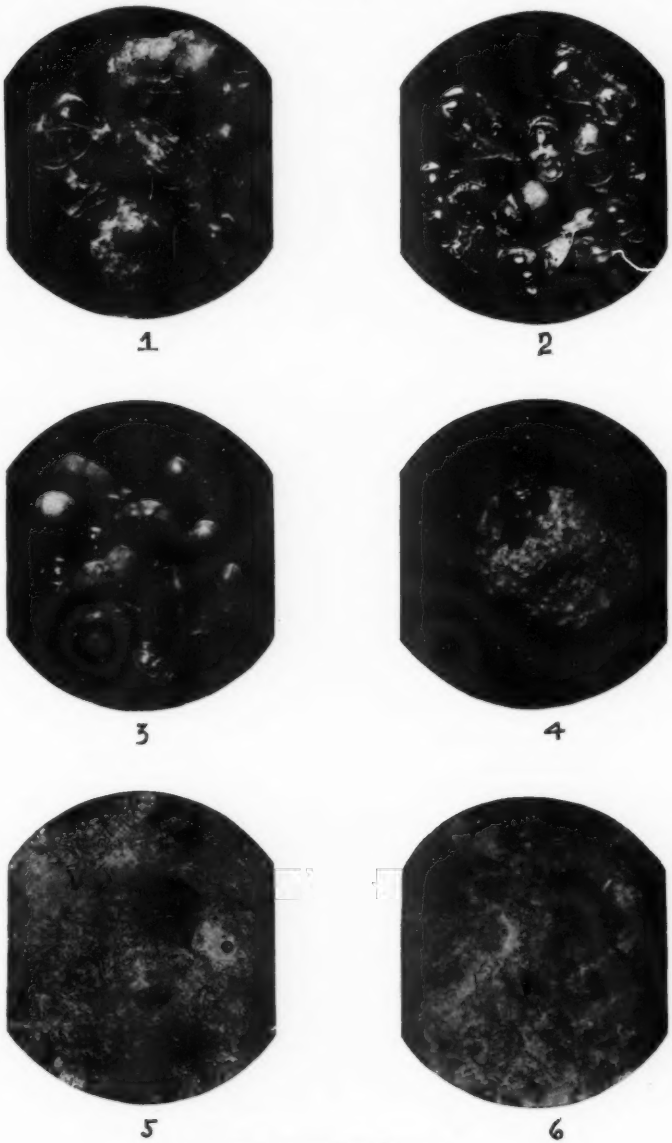
below the size of a two-hundred mesh sieve was washed out. A portion of the finer material which passed through the sieve was caught and examined. After removing the finer material with the stream of water, the remaining part was washed into a folded filter paper in a small funnel. When all the water had passed through, the filter paper and inclosed material was dried on a hot plate at a temperature of about 100° C. The dried residue was then ready for study. This method of standardization gives consistently uniform results, is mechanical, and eliminates the factor of varying personal equation. In rapid determinative work, material which passes through the two-hundred-mesh sieve is not usually examined. However, where volcanic ash is expected, some of the finer material should be examined. Where diatoms are sought other methods of standardization are also necessary.

The dried sample was further standardized by the use of a nest of sieves. However, because of the contamination of the sample, the separation of the material by the various sieves was of little value in this particular sample, other than for convenience in studying. Almost all of the material contaminating the sample was quartz, the grains being nearly all clear and well rounded. Scattered through this foreign material were a few quartzitic pebbles up to five millimeters in diameter. The remainder of the contaminating material ranged in size to less than two-hundred mesh. In this material was also found a fragment of one mollusk shell too small to identify, a few pieces of partly silicified wood, a considerable number of crystals of pyrite, and one fragment of pink orthoclase granite. The reason for considering this material foreign is that many fragments of the tuff were examined and none of the materials mentioned above were found included. The fragments were composed, almost if not entirely, of volcanic material.

The tuff is composed largely of glass fragments, ranging in size from dust to particles slightly more than one millimeter in diameter. The glass fragments are both flat and curving with the former the more abundant. Probably 3 to 5 per cent of the tuff is composed of glass bubbles, either as individual bubbles or individual bubbles or in clusters.

The glass as a whole is very fresh, and only in a small per cent of the fragments has devitrification taken place. Many of both the flat and the curved flakes are minutely perforated. On the other hand some pieces, as much as one millimeter in diameter, are of flawless glass. The flakes are always thin and show irregular fracture.

The bubbles, either as individuals or as clusters, range in size from less than two-hundred mesh to slightly more than one millimeter. In either case there are usually from one to many flat glass surfaces attached. Several bubbles are often in a linear series with the flat glass surfaces arranged radially from the axis of the series. Such clusters resemble very much some of the ribbed *Nodosaria*. Other clusters are arranged in such manner as to resemble *Cristellaria* with thin keels. In fact the clusters show a variety of shapes in the orientation of the individual bubbles.



EXPLANATION OF PLATE 4

FIG. 1.—Glass bubbles from Duhig *et al.* No. 1 Levy, Calcasieu Parish, Louisiana. Magnification approximately 25×.

FIG. 2.—Glass bubbles. Magnification approximately 25×.

FIG. 3.—Glass bubbles partially devitrified. Magnification approximately 25×.

FIG. 4.—Glass bubble partly imbedded in fragmental glass, the original character of the material. Magnification approximately 25×.

FIG. 5.—Thin section of tuff. Magnification approximately 46×.

FIG. 6.—Thin section of tuff. Magnification approximately 46×.

The decanting method of washing samples was also used in this particular sample for comparison of results, but was found too inaccurate for quantitative work. Most of the bubbles are non-perforate or only minutely so. When dry they were filled with air, and the air was not displaced by water when soaking. Consequently when the soaked sample was decanted the first time, most of the glass bubbles floated away. In fact bubbles could be seen floating after stirring but before decanting. The material poured off when decanting was washed on the two-hundred-mesh screen and many glass bubbles were found. Other material was also caught on the two-hundred-mesh screen, but need not be considered here, as the percentages in the residue were not materially changed by the loss.

In thin section the tuff is composed almost wholly if not completely of volcanic material, either as angular glass fragments or as bubbles. The tuff is fairly loose. It is slightly compacted rather than cemented. Devitrification has taken place in only a small part of the fragments.

The glass itself is a quite acidic one with N. 1.490 to N. 1.505. Most of it, however, is with N. 1.495 to N. 1.500.

Unfortunately no other samples were received from this well by the writer. Consequently a laboratory determination of the stratigraphic position of the ash cannot be given. However, the base of the Lissie gravel in this well is at a depth of 552 feet. This would place the ash 958 feet below the base of the Lissie gravel.

CONCLUSIONS

1. A nearly pure tuff bed exists at 1,510 feet in the Duhig *et al.* No. 1 Levy in the Hayes district of Calcasieu Parish, Louisiana.
2. The thickness of the bed is not known.
3. The lateral extent of the bed is not known.
4. Nothing is known of the source of the material.
5. The glass is fresh and coarser than in most of the tuffs heretofore noted by the writer.
6. The glass is quite acidic, having an index of refraction between 1.490 and 1.505, but chiefly between 1.495 and 1.500.

MARCUS A. HANNA

HOUSTON, TEXAS

THE GRANITE RIDGE OF KANSAS

The Granite Ridge of Kansas strikes from north to south across the state, as a southward pitching anticlinal fold. Pennsylvanian beds rest across the truncated ridge. Along the axis, from Chase County south, Pennsylvanian beds rest upon the "siliceous" lime of Cambro-Ordovician age. On the flanks and in some of the saddles that cut across the axis, the Pennsylvanian rests upon a varying thickness of Mississippian limestones. Mississippian seas extended across the location of the present

ridge from the Kansas-Oklahoma line to at least the south line of Chase County and probably for its entire extent.

In late Mississippian or early Pennsylvanian time the entire region emerged, and with its emergence the Granite Ridge was elevated for a thousand feet or more above the surrounding country. In the long time interval which intervened between the withdrawal of the Mississippian seas and the advance of the Pennsylvanian seas, erosion, working more rapidly on the higher portions, stripped the Mississippian and even older rocks off the axis of the ridge. The ridge was thus reduced practically to the base level of the surrounding country, which at no time appears to have attained an altitude of more than 50 or 100 feet above sea-level. Just before the advance of the Pennsylvanian seas, the Granite Ridge of Kansas might be likened in appearance to that of the present western extension of the Arbuckle Mountains in northern Carter County, Oklahoma.

That portion of the ridge south of T. 23 S. appears to have received a greater part of the normal Cherokee section (basal Pennsylvanian) as deposited elsewhere in Butler County. Northward, from T. 23 S., the truncated portion of the ridge received less and less Cherokee sediments. The lower Cherokee shales, which are evidently prerequisite as source beds for the accumulation of oil in this district whether in the Bartlesville, Burbank, Mississippi lime, or "siliceous" lime reservoirs, are absent northward. At time of deposition, these lower oil source shales bent in a V-shape fashion (opening northward) out around the edges of the ridge.

All deep oil in the Augusta–El Dorado–Peabody–Elbing districts of Butler and Marion counties occurs in an upper porous zone of the "siliceous" lime in contact with lower Cherokee shales. One exception is the southeast extension of the El Dorado field, where a post-"siliceous" pre-Chattanooga sand affords oil under a thin section of Mississippi lime. From this relation one may infer that prospecting for "siliceous" lime production of the El Dorado–Elbing type should be confined to areas where "siliceous" lime is known to be in contact with an adequate body of Cherokee shales. Correspondingly, similar pools should not be expected north of the V-shaped contact of lower Cherokee shales with Cambro-Ordovician rocks.

HENRY A. LEY

MISSISSIPPI LIME WEST OF THE GRANITE RIDGE IN KANSAS

The presence of Mississippi lime west of the Granite Ridge in Kansas has been questioned at times. Deep drilling has definitely established its presence in Sumner, Sedgwick, Harvey, and western Butler counties. In

these counties, all lying west of the Granite Ridge, the Mississippian section is similar in lithologic characteristics and thickness to the normal section penetrated east of the ridge. The ridge interrupted the east to west continuity, but did not prevent its deposition to the west. Mississippian seas covered the present location of the ridge as far north as northern Butler County, and probably its entire extension northward.

All deep tests in Sumner County except a few in the extreme southwestern part, report from 300 to 400 feet of Mississippi lime, resting upon Chattanooga shale. The shale in turn rests upon what appears to be a widespread occurrence of a post-"siliceous" lime pre-Chattanooga sand. A test now drilling by the Champlin Refining Company, on the Stevenson farm in section 9, T. 30 S., R. 1 W., 20 miles west of the ridge, reports 1,429 feet of pre-Pennsylvanian sedimentary rocks resting upon the granite floor. Twenty-three miles east of the ridge, a test in section 9, T. 35 S., R. 6 E., penetrated 1,435 feet of pre-Pennsylvanian rocks above the granite. Over southeastern Kansas, between the Granite Ridge on the west and Ozarkia on the east, from 1,300 to 1,400 feet of sedimentary rocks are commonly penetrated between the base of the Pennsylvanian and the granite floor. Northward across the state there appears to be a regional thinning of the pre-Pennsylvanian section.

A normal Mississippian section is present over the east half of Sedgwick County, and probably extends westward to and beyond Kingman County. Presumably, it should extend into and beyond the regional syncline separating the Granite Ridge province on the east from the Russell County province on the west. From the axis of the ridge westward in Butler County, the Mississippian section gradually increases in thickness until in most of Range 3 it again attains its normal thickness. There is little or no Mississippian present in Chase County west of the ridge, but in Harvey County it again appears.

From the evidence at hand, it seems unlikely that pools of the Augusta–El Dorado–Peabody–Elbing type will be found west of the Granite Ridge and east of the regional syncline mentioned above. In this province, oil fields in pre-Pennsylvanian beds will probably be of the Virgil (eastern Greenwood County) types if occurring in the upper part of the Mississippi lime; of the Montgomery County type if occurring in the "siliceous" lime; and of the Creek-Okmulgee County, Oklahoma, type if productive in the post-"siliceous" pre-Chattanooga sands.

HENRY A. LEY

REVIEWS AND NEW PUBLICATIONS

The Revue de Géologie

The Revue de Géologie et des sciences connexes, published at Liège, Belgium, contains concise summaries of many geologic contributions of interest to petroleum geologists. Volume 6, No. 1 (1925), contains 151 short abstracts.

No. 88 mentions two occurrences of oil in the region of Semiryechensk, Turkestan, described by V. Weber in a *Bulletin of the Geological Committee*, Petrograd, 1918.

No. 100 is an abstract of an article dealing with bituminous shales in France, and published in *Rassegna Minenaria*, Rome, Italy, April 15, 1924. There are in France seven principal basins, the most important being the Bassin de l'Autunois, in which oil shales occur at the base of the Permian. In the lower horizon are four beds of shale 2.5, 1.8, 2, and 4 m. thick; one bed 2.5–3 m. thick occurs in the middle horizon; the upper horizon contains twelve beds 0.8–3 m. thick in its upper part and six beds 1.25–3 m. thick in the lower part. A ton of these shales yields 90 liters of oil, which, when subjected to fractional distillation, produces 5 liters of benzine, 20 liters of pétrole (motor fuel), 10 liters of heavy oils, 35 liters of goudron, 3 kgs. of paraffin, and 12 kgs. of ammonium sulphate. The shale production in 1923 amounted to 70,000 tons.

The Bassin de l'Aumance, with one workable bed 1–2.2 m. thick, produced 61,000 tons of oil shale in 1923. The Bassin de Mansque is divided into two parts by an anticline. The main bed produces about 160 liters per ton. The other four basins are of lesser importance. France's oil-shale industry is passing a critical period. Reserves are estimated at 50 million tons, and their exploitation would yield a relatively small amount of liquid fuel.

ADAM WRÓBLEWSKI

OIL IN PERU

In the October and November numbers of the *Bulletin of the Pan American Union*,[1] Sr. R. A. Deustua contributes a comprehensive paper on the "Explored Oil Fields of Peru." He describes these under the following heads: Tumbes-Paita fields; Huancané and Islaicocha fields; Junín fields: and Mountain fields.

The Tumbes-Paita fields are situated along the Pacific Coast of northern Peru. The oil, which varies in gravity from 34.6° Baumé to 39.3° Baumé, is produced from the Negritos and Lobitos formations, both Eocene, and the

[1] Vol. 59 (Washington, D. C., 1925), pp. 981–99, 1120–32.

Zorritos formation, Miocene. Production is obtained from varying depths, the deepest well having been drilled to over 5,000 feet. Initial yields of as much as 3,000 barrels per day have been known, although the usual flush production is less than 500 barrels. Some of the wells have been long-lived, yielding for more than 20 years.

In the Tumbes-Paita district, the Tertiary formations lie unconformably upon a complex of rocks from pre-Paleozoic to Cretaceous age, consisting of igneous and metamorphic rocks, associated with some limestones. The Tertiary beds have been moderately folded and strongly faulted. Unconformably upon the faulted Tertiary is a series of marine terrace gravels, the "Tablazo formation," up to 100 feet in thickness, absent in some parts, but where present serving as a blanket to conceal the structure of the older formations.

The Huancané and Islaicocha fields are east of the Andes Range. The former is on the north shore of Lake Titicaca, and the latter is some miles farther northwest, 28 miles west of Chuquibambilla station on the Juliaca-Cuzco Railroad. In the Huancané field some light gravity oil has been produced at Pirín, 14 miles ease of Juliaca. This oil comes from beds of Devonian age, here folded in an asymmetrical anticline. At Islaicocha the same formations occur, also folded, but no development has been undertaken here. In both fields, seepages of oil and gas are common. In the Islaicocha field some of these seepages are associated with post-Paleozoic igneous intrusions which broke through the petroliferous strata. These fields near Lake Titicaca are comparable with the Caupolicán fields of Bolivia.

In the Department of Junín, east of Lima, Sr. Deustua mentions petroliferous sandstones and limestones of Cretaceous age, but there has been no actual development for oil.

The Mountain fields, also, are included in the classification because of seepages, not because of oil production from wells. These fields are in the provinces of Alto, Amazonas, Ucayali, San Martin, Huallaga, and Bongará. They are distributed along Santiago River, and lower Ucayali and Huallaga rivers. The stratigraphic and structural character of this region has not been ascertained, although it is known that Tertiary, Cretaceous, and Jurassic strata are widely exposed.

FREDERIC H. LAHEE

THE ASSOCIATION ROUND TABLE

MEETING OF THE GEOLOGICAL SOCIETY OF AMERICA

The annual meeting of the Geological Society of America, which was held this year at New Haven, Connecticut, in joint session with the Paleontological and Mineralogical Societies of America, was attended by many of the members of the American Association of Petroleum Geologists, who also were well represented on the program. Members of the Association who delivered papers were: Eliot Blackwelder, C. E. Dobbin, Charles J. Hares, Alfred C. Lane, Kirtley F. Mather, Wilbur A. Nelson, Sidney Powers, Wallace Pratt, John L. Rich, Edmund M. Spieker, W. Taylor Thom, Jr., and W. H. Twenhofel. Of particular interest to petroleum geologists were the papers by John L. Rich, who presented new data on "Buried Pennsylvanian Channels and Sand Bars of Eastern Kansas"; by Wallace Pratt and Douglas W. Johnson on "A Recent Local Subsidence of the Gulf Coast of Texas," in which they told of the evidence bearing on the reasons for subsidence of the land surface of the Goose Creek Field of Texas; and by Edson S. Bastin on "The Problem of the Natural Reduction of Sulphates." This last paper told of the discovery of anaerobic bacteria in oil field waters taken from wells yielding oil and water from sands in Illinois, ranging in age from the Trenton to the Pennsylvanian, and from a deep well in eastern Oklahoma. The discovery of these sulphate-reducing bacteria opens a broad field of speculation, for, if it can be positively established that their presence is not due to the contamination with surface waters, and the evidence against such an origin is even now fairly conclusive, it will appear that anaerobic bacteria have existed in oil field waters, and presumably in oil field sands, since the deposition of the sands, and any theory accounting for the origin of oil will have to reckon with their presence.

At the banquet of the Geological Society of America, E. DeGolyer, president of the American Association of Petroleum Geologists, was one of the speakers, and devoted his time to telling the Geological Society of America about the American Association of Petroleum Geologists, and opening the way for a more intimate contact between the two organizations.

K. C. HEALD

MEETING OF THE PACIFIC SECTION

A meeting of the Pacific Section of the American Association of Petroleum Geologists was held in the Palace Hotel, San Francisco, November 19 and 20. Attendance was very good, as is evidenced by the fact that at the dinner held on Thursday evening there were about 100 present, out of 134 members of

the American Association who are active on the Pacific Coast at the present time.

The Thursday morning session was given over to technical papers. At a short business meeting on Thursday afternoon E. F. Davis was elected chairman for the coming year, and Carrol M. Wagner secretary-treasurer. The secretary was instructed to prepare a request, to be transmitted to the parent organization, that in each issue of the *Bulletin* some place be set aside for a notice as to the officers of the Pacific Section and the address of the secretary-treasurer, to appear with a request that members transferring to the Pacific Coast advise the local secretary-treasurer of their transfer and their desire to affiliate with the Pacific Coast Section. This is to help us in keeping in closer touch with the membership of the parent organization, a problem which is somewhat difficult in view of the constant changes of address in the profession.

The papers read before the meeting were all received with interest and there was much hearty discussion of the many debatable suggestions advanced. We were fortunate in having several visitors from the Mid-Continent district, who were able to contribute helpfully to our discussions. An outline of the program follows.

We believe that the success of this meeting has fully justified our belief that a local section of the American Association should thrive in this region.

PROGRAM

1. The Value of Bore Hole Surveying in the Discovery and Development of Oil Fields.....ALEXANDER ANDERSON
2. An Interesting Example of the Survey of a Deep Bore Hole
N. L. TALIAFERRO AND F. S. HUDSON
3. Analysis of Rotary Drillers' Logs and Sub-surface Correlations in Southern California Oil Fields.....HOWARD W. KITSON
4. Correlative Value of the Microlithology and Micropaleontology of the Oil-bearing Formations in the Sunset-Midway and Kern River Oil Fields
PAUL P. GOUDKOFF
5. Were Diatoms the Chief Source of California Oil?
GEORGE M. CUNNINGHAM
6. Relationship of Foraminifera to the Origin of California Petroleum
THOMAS F. STIPP
7. Generic Distinctions among Orthophragmina, Nummulites, Lepidocyclina, Miogypsina, Spiroclypeus and Cycloclypeus for the Field Geologists of the East Indies.....I. M. VAN DER VLERK AND R. E. DICKERSON
8. Age and Correlation of the Moreno Shales..J. A. TAFF AND G. D. HANNA
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AT HOME AND ABROAD

CURRENT NEWS AND PERSONAL ITEMS OF THE PROFESSION

PHILIP MAVERICK, who has been with the Texas Company as geologist for about five years, has recently opened offices as consulting geologist at San Angelo, Texas.

EUGENE A. STEPHENSON, who has served as geologist for the South Penn Oil Company, Pittsburgh, for a number of years, has recently become associated with Ralph E. Davis, consulting engineer, Pittsburgh.

CLARENCE O. DAY, of Shreveport, Louisiana, is in charge of drilling operations for the Phillips Petroleum Corporation at Smackover, Arkansas.

R. L. BECKELHYMER, geologist for the Phillips Petroleum Corporation, has been working for several months in southern Arkansas wildcat territory. Mr. Beckelhymer's address is Box 741, Little Rock, Arkansas.

L. W. PETRIE has established field headquarters at Camden, Arkansas, for the Shreveport office of the Roxana Petroleum Corporation.

W. C. SPOONER, of Shreveport, Louisiana, was appointed marshal of the geological division of the biggest parade ever staged in Shreveport, Louisiana, which celebrated oil and gas industry day, October 31, during the Louisiana State Fair. Mr. Spooner was called on business to New York City and Washington, D.C., at the last minute and delegated his duties in the big show to S. C. STATHERS, vice-president of the Shreveport Geological Society.

The U. S. GEOLOGICAL SURVEY has opened an office in the City Bank building, Shreveport, Louisiana, which is temporarily in charge of Miss Eula Bandegaer. C. H. DANE, of Washington, D.C., and PAUL D. TORREY, lately stationed at Denver, Colorado, both of the Survey, have been working in Shreveport territory during the summer, and more recently have been doing field work on the Cretaceous of southwestern Arkansas under the direction of L. W. STEPHENSON.

J. F. HOSTERMAN, division geologist for the Amerada Petroleum Corporation at Shreveport, Louisiana, and Miss Christine Landes, of Lawton, Oklahoma, were married, November 2, 1925, at Lawton. Mr. and Mrs. Hosterman are at home at 525½ Wichita Street, Shreveport.

O. L. BRACE, in charge of the Shreveport, Louisiana, office of the Marland Oil Company of Texas, has enlarged the local office and is now established at 732 Giddens-Lane Building.

HAROLD E. BOYD, of H. L. Doherty and Company, 60 Wall Street, New York City, paid a visit to Shreveport, Louisiana, last November in behalf of the Natural Gas and Fuel Corporation.

S. S. PRICE, geologist for the Dixie Oil Company, Tulsa, Oklahoma, visited the Shreveport, Louisiana, office of the company several days last November.

A. F. CRIDER, in charge of the geological department of the Dixie Oil Company at Shreveport, Louisiana, and J. O. NELSON, geologist from the Chicago offices of the company, made a reconnaissance trip into southwestern Texas last November, visiting the San Antonio, San Angelo, and other districts. Mr. Nelson visited all the Dixie offices in Oklahoma, Louisiana, and Texas.

In the Bureau of Economic Geology of the University of Texas, DR. E. H. SELLARDS, chief geologist, has been advanced to associate director. MR. W. S. ADKINS, formerly a member of the Bureau staff and more recently engaged in private geologic work in Mexico, has returned as associate geologist. He has been given leave of absence for one year from the University, which he is using in advanced study in France. DR. JOHN T. LONSDALE, formerly of the University of Oklahoma, has been called to the place of associate geologist in the Bureau.

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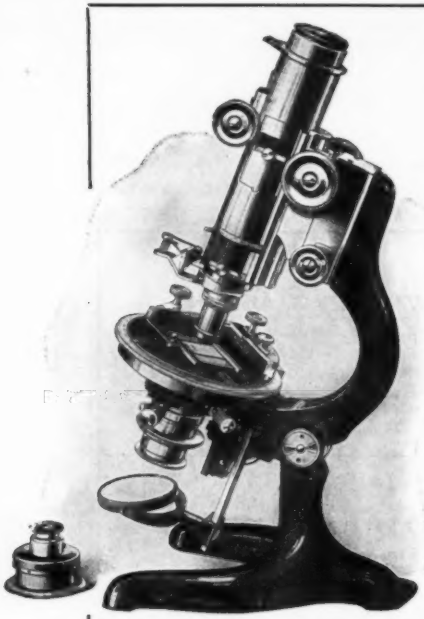

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Members of the American Association of Petroleum Geology transferring to the Pacific Coast are requested to advise the local secretary-treasurer of their transfer and their desire to affiliate with the Pacific Coast Section.